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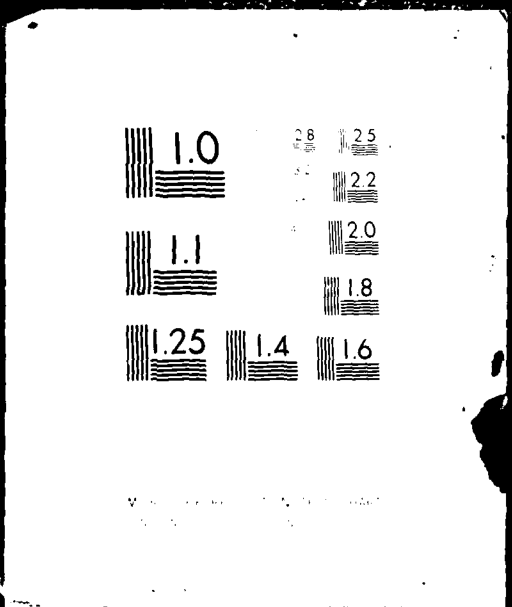

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Towed Thermistor Chain Observations Across the Gulf Stream

by

R. J. Baumann, L. M. deWitt, M. D. Levine,
C. A. Paulson and J. D. Wagner

Office of Naval Research
N00014-79-C-0004
NR 083-102

Reference 82-3
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Vertical cross-sections of temperature in the Sargasso Sea and across the Gulf Stream and a warm core ring were obtained with a towed thermistor chain in September 1981. The thermistors were distributed in the upper 70 to 120 m during three runs. Salinity was also measured at two locations on the towed chain and in the ship's lab. A temperature inversion of about 4°C was found near the edge of the warm core ring.

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TABLE OF CONTENTS

INTRODUCTION

This report presents observations of temperature in the upper ocean obtained by use of a towed thermistor chain. The observations were taken aboard the R/V OCEANUS on a cruise out of Woods Hole, Massachusetts in September 1981. The primary purpose of the cruise was to recover and deploy moorings at 34°N, 70°W as a part of Mel Briscoe's Long-Term Upper Ocean Study (LOTUS). The objectives of our participation were:

- To investigate the structure across the Gulf Stream and warm core rings.
- To investigate the spatial structure of the upper ocean in the vicinity of Mel Briscoe's LOTUS mooring.
- To test the towed chain after it was refurbished and lengthened to 165 m.
- To test improved versions of conductivity sensors installed on the towed chain.

INSTRUMENTATION

The towed chain system and its use in other experiments have been previously described by Spoering (1979), Baumann et al. (1980) and Paulson et al. (1980). The chain was refurbished and lengthened to 165 m in the months preceeding its use on the LOTUS cruise. The refurbishment included the replacement of electrical conductors, strain member and damaged fairing. In addition to thermistors and pressure sensors, improved conductivity sensors were installed at two locations on the chain. The locations of the sensors relative to the depressor and the mean depths of operating sensors for each run are given in Table 1.

In addition to the measurements made on the towed chain, surface salinity was measured throughout the cruise by use of a flow-through system in the ship's lab. This system is described by Baumann (1981). Sea water from the ship's sea water system was circulated through the salinometer. Digital values of temperature and conductivity were recorded once per minute.

Table 1. Location and mean depth of sensors on the towed chain. The stations have either a temperature, conductivity or pressure sensor installed, denoted by T, C or P. The distance along the chain from the depressor to the sensors is denoted by S which has units of "chain-meters". One chain-meter equals 40 in. or 1.016 m.

Channel No.	Station	S (Chain-meters)	Depth of Operating Sensors (m) Run 1	Run 2	Run 3
0	T0	8			
1	P0	10	68.4	116.7	107.2
2	T1	12	66.3	114.7	105.2
3	T2	16	62.3	110.6	101.1
4	C0	16.5	61.8	110.1	100.6
5	T3	17	61.3	109.6	100.1
7	T4	20	58.3	106.6	97.1
8	T5	24			
9	T6	28	50.3	98.5	89.2
10	T7	32	46.3	94.5	85.2
11	T8	36	42.3	90.5	81.3
12	T9	40	38.4	86.5	77.5
13	T10	44	34.5	82.5	73.6
14	T11	48			
15	T12	52			
16	T13	56	22.9	70.7	62.3
17	P1	58			
18	T14	60	19.1	66.8	58.6
19	T15	64	15.3	62.8	55.0
20	T16	68			
21	T17	72	7.9	55.1	47.8
22	T18	76			
23	T19	80		47.4	40.7
24	T20	84		43.6	37.3
25	T21	88		39.8	33.8
26	T22	92			
27	T23	96		32.2	27.1
28	T24	100		28.5	23.8
29	T25	104		24.8	20.5
30	P2	106		22.9	18.9
31	T26	108		21.1	17.3
32	T27	112		17.4	14.1
33	T28	116			
34	C1	116.5		13.3	10.6
35	T29	117		12.8	10.2
36	T30	120		10.1	7.8

OBSERVATIONS

The thermistor chain was towed on three occasions during the cruise. The tow tracks and the ship's track during the entire cruise are shown in Figure 1. The tow tracks are shown in more detail in Figure 2 and bihourly positions are tabulated in Table 2. As the result of a malfunction, there was no data recorded between 0830 and 0852 on 12 September during Run 1. Data from the period 0715 to 0830 was not processed because of the previously noted malfunction.

The towed chain tended to kite, i.e., tow off to the side during the cruise. This had not occurred on previous cruises and is believed to have been caused by excessive friction between the strain member and fairing. The excessive friction originated from a splice in the strain member and the use of a larger diameter strain member than before.

The depths of the sensors (see Table 2) were estimated by fitting a model of the chain shape (Baumann et al., 1979; Paulson et al., 1980) to mean observations of depth at 10.2 and 107.7 m above the depressor. An artificially large drag coefficient was required for the fit because of the kiting. Values of $C A \rho$ were 4.0, 4.5 and 5.0 for Runs 1, 2 and 3 respectively where C is the drag coefficient, A is the cross-sectional area of the chain per unit length and ρ is the density of water. These values may be compared to $C A \rho = 1.7$ used in the FRONTS experiment where the chain did not kite.

The temperature conductivity and pressure observations were low-pass filtered by computing sequential 30-s averages. Filtering removes fluctuations caused by variations in sensor depths associated with surface gravity waves and the pitch, roll and heave of the ship. However there still

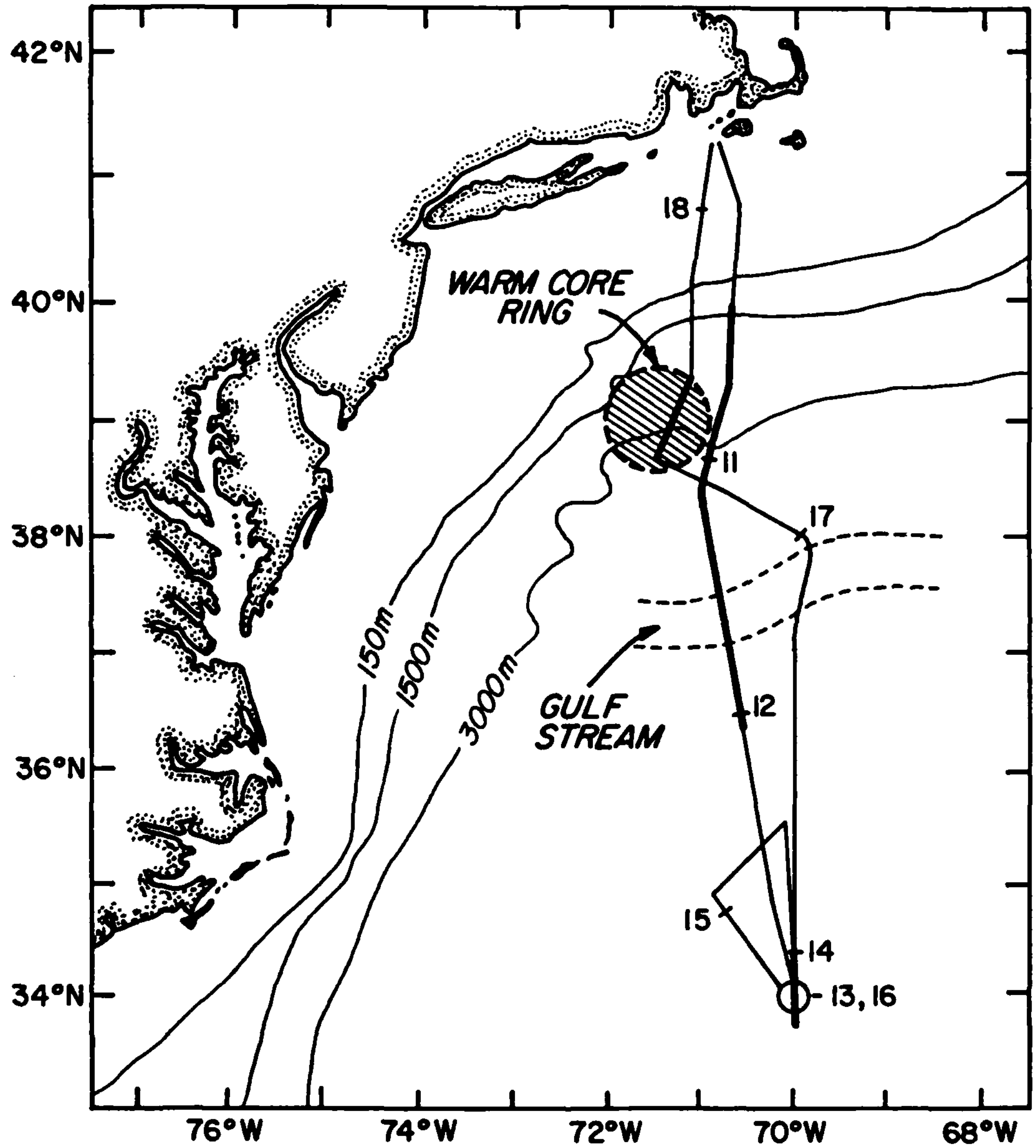

Figure 1. Map showing the ship's cruise track and approximate locations of the Gulf Stream and a warm core ring. The dates in September are plotted at the noon position on the cruise track. The three heavy segments of the cruise track correspond to tows of the thermistor chain. The circle at 34N, 70W encloses unplotted track associated with mooring work.

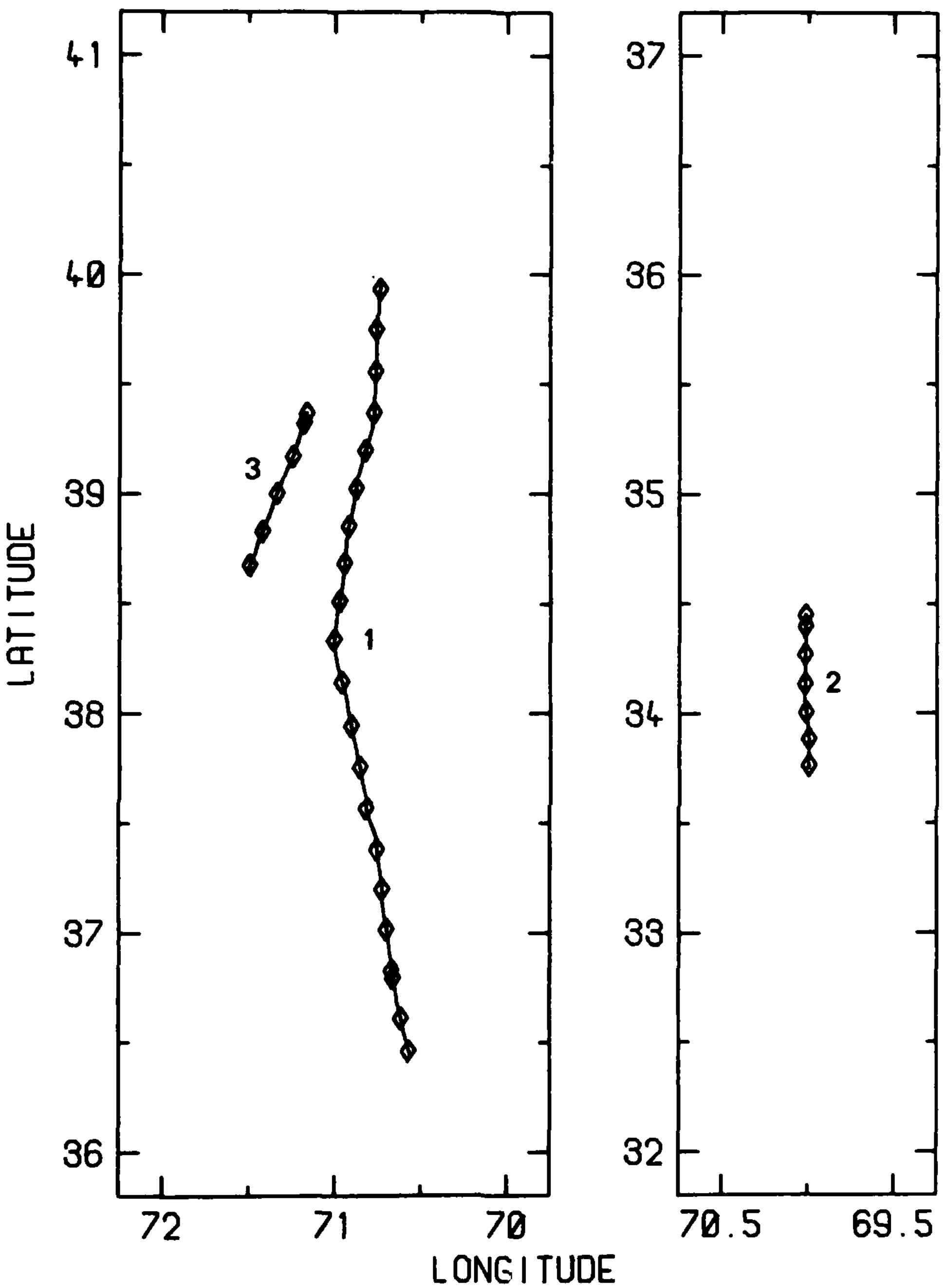

Figure 2. Track of the towed thermistor chain during Runs 1, 2 and 3. Symbols are plotted at the beginning and end of each Run and at two-hour intervals from the beginning with the exception of Run 1 where there is a break near the end.

Table 2. Two-hourly LORAN-C positions during the tows. Distance traveled, direction and speed are computed for the interval subsequent to the given time and position.

Run No.	Date (Sep GMT)	Time (GMT)	N. Lat. (deg)	N. Lat. (min)	W. Long. (deg)	W. Long. (min)	Dist. (km)	Dir. (deg)	Speed (m/s)
1	10	2230	39	55.80	70	44.38	20.11	184.6	2.79
	11	0030	39	44.97	70	45.51	21.66	181.6	3.01
		0230	39	33.27	70	45.93	20.51	182.8	2.85
		0430	39	22.20	70	46.62	19.76	191.8	2.74
		0630	39	11.75	70	49.43	19.37	193.6	2.69
		0830	39	1.57	70	52.60	19.47	190.5	2.70
		1030	38	51.22	70	55.05	18.85	187.2	2.62
		1230	38	41.11	70	56.68	19.26	187.6	2.67
		1430	38	30.79	70	58.44	20.04	188.3	2.78
		1630	38	20.07	71	0.42	21.74	169.1	3.02
		1830	38	8.53	70	57.60	22.31	167.7	3.10
		2030	37	56.75	70	54.35	21.36	168.5	2.97
		2230	37	45.43	70	51.45	21.11	169.2	2.93
	12	0030	37	34.22	70	48.77	21.85	165.9	3.04
		0230	37	22.76	70	45.16	19.71	173.1	2.74
		0430	37	12.18	70	43.55	20.58	173.6	2.86
		0630	37	1.12	70	41.99	21.31	172.4	2.96
		0830	36	49.70	70	40.10	-	-	-
		0852	36	47.59	70	39.61	20.88	169.1	2.90
		1052	36	36.50	70	36.94	16.61	166.4	2.88
		1228	36	27.77	70	34.33	-	-	-
2	14	0130	33	45.85	69	59.81	13.64	000.3	1.90
		0330	33	53.23	69	59.76	13.23	354.8	1.84
		0530	34	0.36	70	0.54	14.35	357.0	1.99
		0730	34	8.11	70	1.03	14.81	001.1	2.06
		0930	34	16.12	70	0.85	14.26	000.6	1.98
		1130	34	23.84	70	0.76	5.71	357.1	1.73
		1225	34	26.92	70	0.95	-	-	-
3	17	1915	38	40.52	71	29.62	18.39	20.8	2.55
		2115	38	49.81	71	25.12	20.37	20.7	2.83
		2315	39	0.11	71	20.15	20.14	22.8	2.80
	18	0115	39	10.14	71	14.74	17.97	17.9	2.50
		0315	39	19.39	71	10.90	4.77	16.8	2.27
		0350	39	21.85	71	9.94	-	-	-

remain fluctuations associated with kiting of the chain. The filtered observations are shown in Appendices A and B.

Filtered observations of depth measured by one of the pressure sensors are shown in Appendix B together with the depths of isotherms. There were errors in the pressure measurements caused by a ground loop to sea water. These errors appear as long term drifts and sudden changes in measured depth as occurred for example at 2340 on 10 September (Appendix B).

Observations of surface salinity throughout the cruise and surface temperature and density during the tows of the chain are shown in Figures 3, 4 and 5. The fluctuations of surface variables show the location and characteristics of shelf, slope and Sargasso water, a warm core ring, the Gulf Stream and various fronts.

The northern edge of the Gulf Stream was crossed at about 0100 GMT on 12 September (Figure 3). The edge was characterized by a narrow band of low-salinity water, sudden increase in temperature and a sudden decrease in density. The band of low-salinity water has been often observed (see Stommel, 1966). Salinity and temperature fluctuations within the Stream were generally in phase and associated density fluctuations were therefore small. The southern edge of the Gulf Stream was crossed at about 0530 GMT on 12 September. The southern edge exhibited a sudden decrease in temperature and a corresponding increase in density. There was also a temperature and density anomaly that occurred between 0530 and 1030 on 12 September. The relationship of this anomaly to the Gulf Stream is uncertain. The chain was not being towed when the ship crossed the Gulf Stream while heading north on 17 September. However, the salinity record is qualitatively similar to the record from the crossing on 12 September.

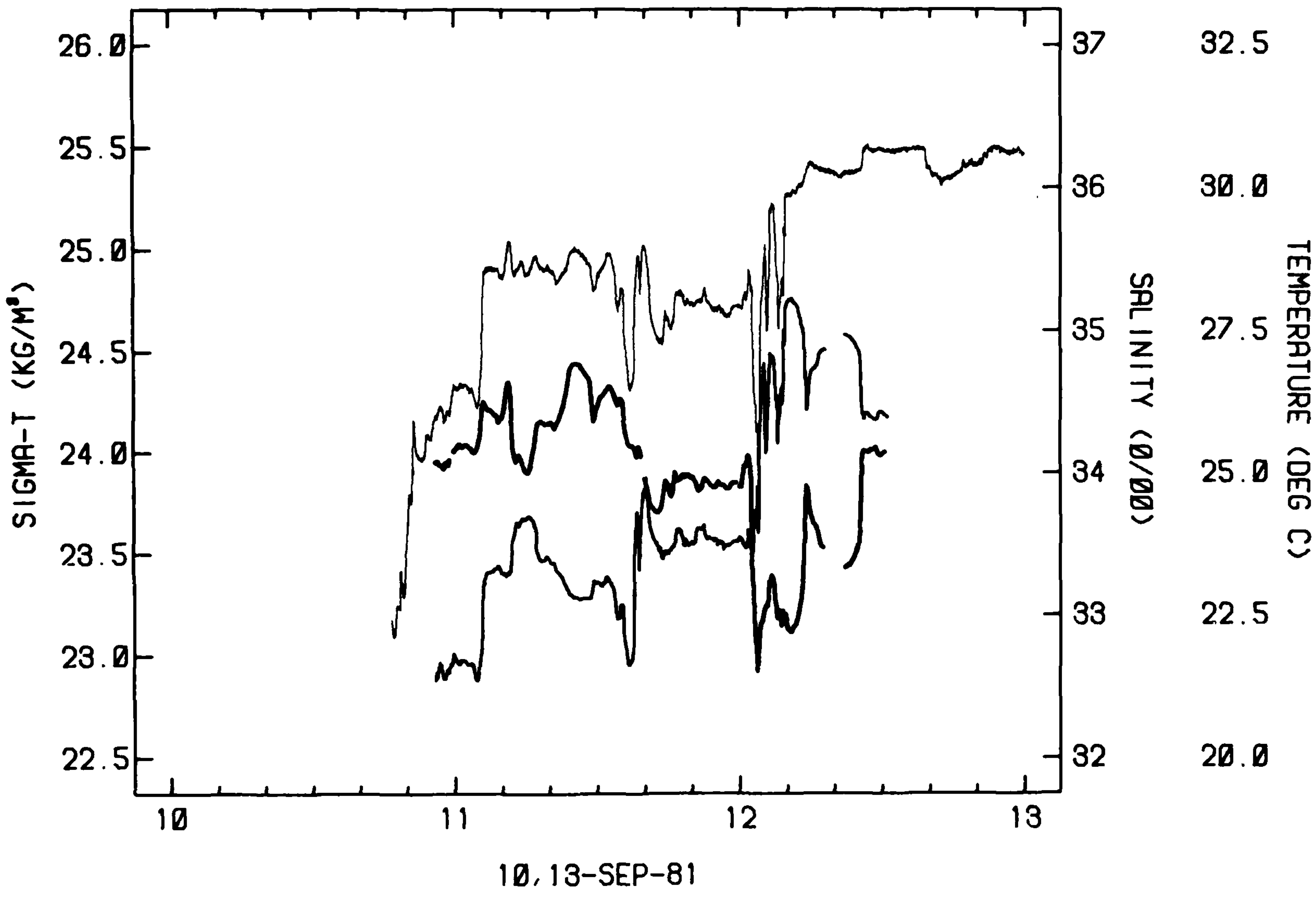

Figure 3. Surface salinity (light line), temperature (medium line) and density (heavy line) from 10 to 13 September.

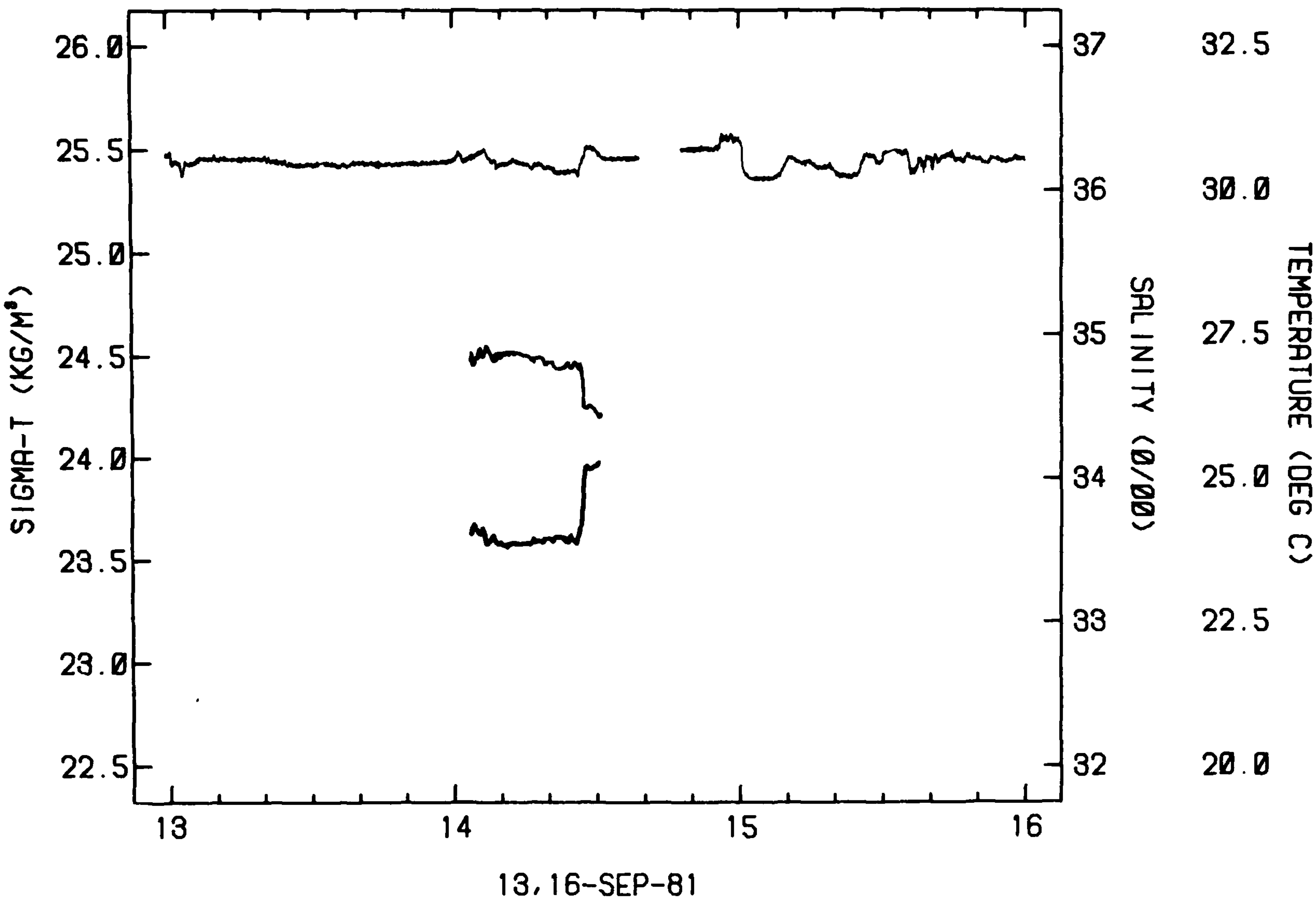

Figure 4. Surface salinity (light line), temperature (medium line) and density (heavy line) from 13 to 16 September.

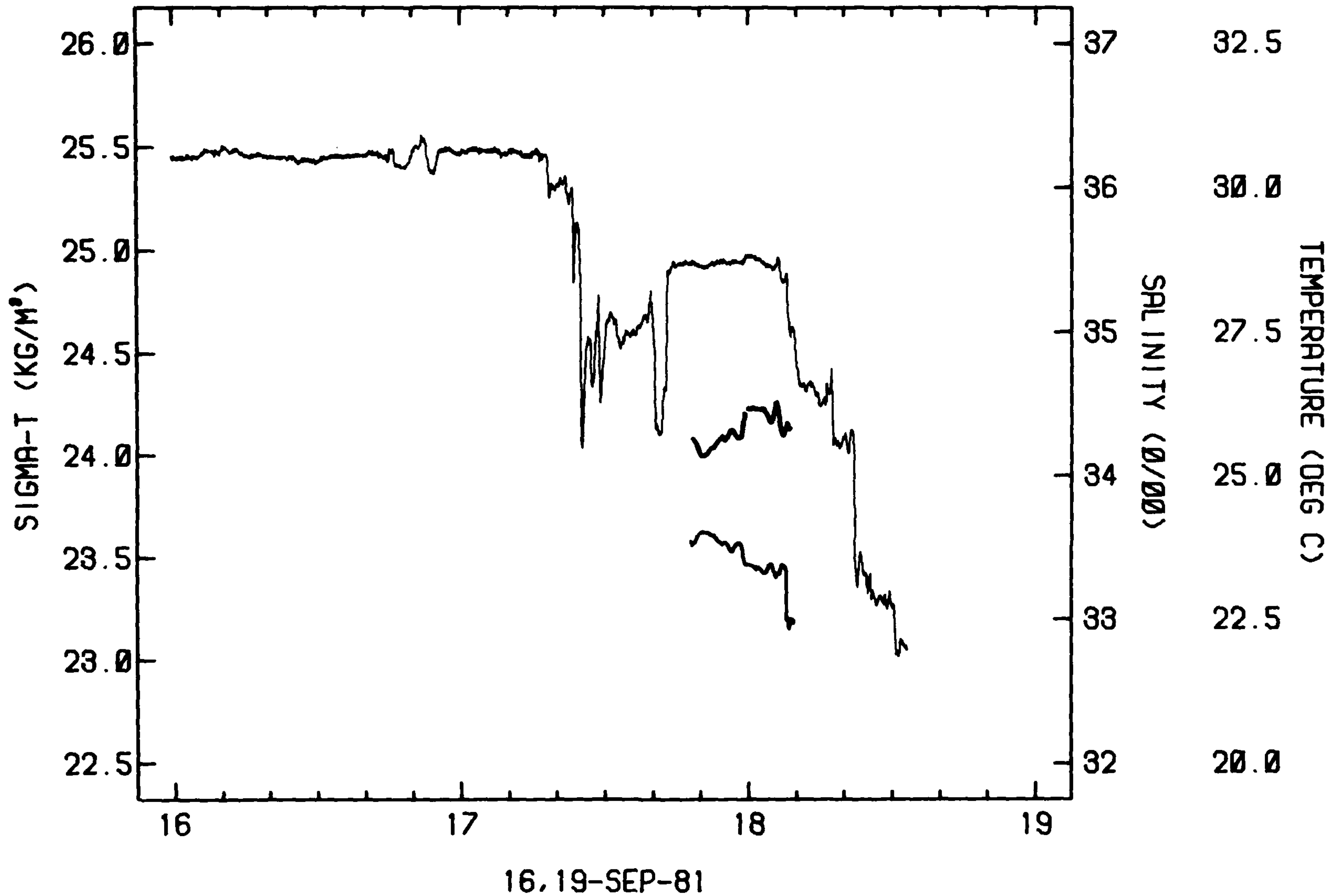

Figure 5. Surface salinity (light line), temperature (medium line) and density (heavy line) from 16 to 19 September.

In particular, there is a band of low-salinity water at the northern edge of the Stream shown in Figure 5 at about 1000 on 17 September.

A front was observed in the Sargasso Sea during a tow of the chain on 14 September (Figure 4). The surface expression of the front was marked by changes in salinity, temperature and density of 0.1°/₀₀, 0.7°C and 0.4 kg m^{-3} respectively.

The last tow, on 18 and 19 September, began in the interior of a warm core ring (Figure 1) and proceeded across the edge at about 0315 on 18 September. The surface properties of the ring are shown in Figure 5. The surface is warmer and more saline than the surrounding water. The edge of the ring was characterized by a change in salinity of 0.5°/₀₀, a change in temperature of 0.9°C and negligible change in density. There was a band of low-salinity water on the south side of the ring more than 1°/₀₀ less saline than surface water inside the ring. Subsurface temperature structure associated with the northern edge of the ring is shown in Figures 6 and 7. There is a temperature inversion between 48 and 105 m depth which exceeds 3°C. The maximum value of the inversion irrespective of depth is about 4°C (Figure 7).

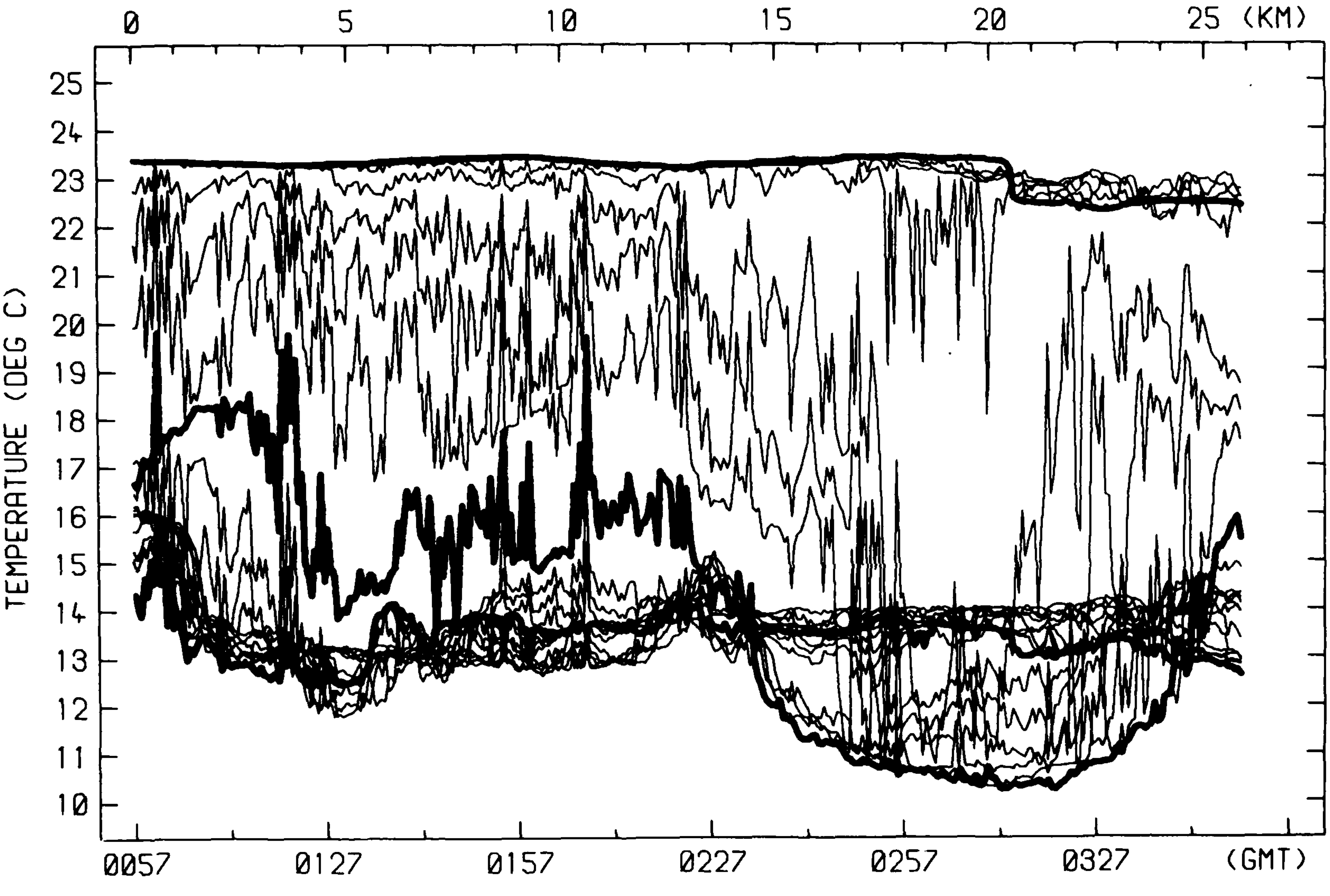

Figure 6. Temperature structure between the depths of 8 and 105 m observed on a tow of a thermistor chain from the inside to the outside of a warm core ring. Temperatures from depths of 8, 48 and 105 m are heavy lines.

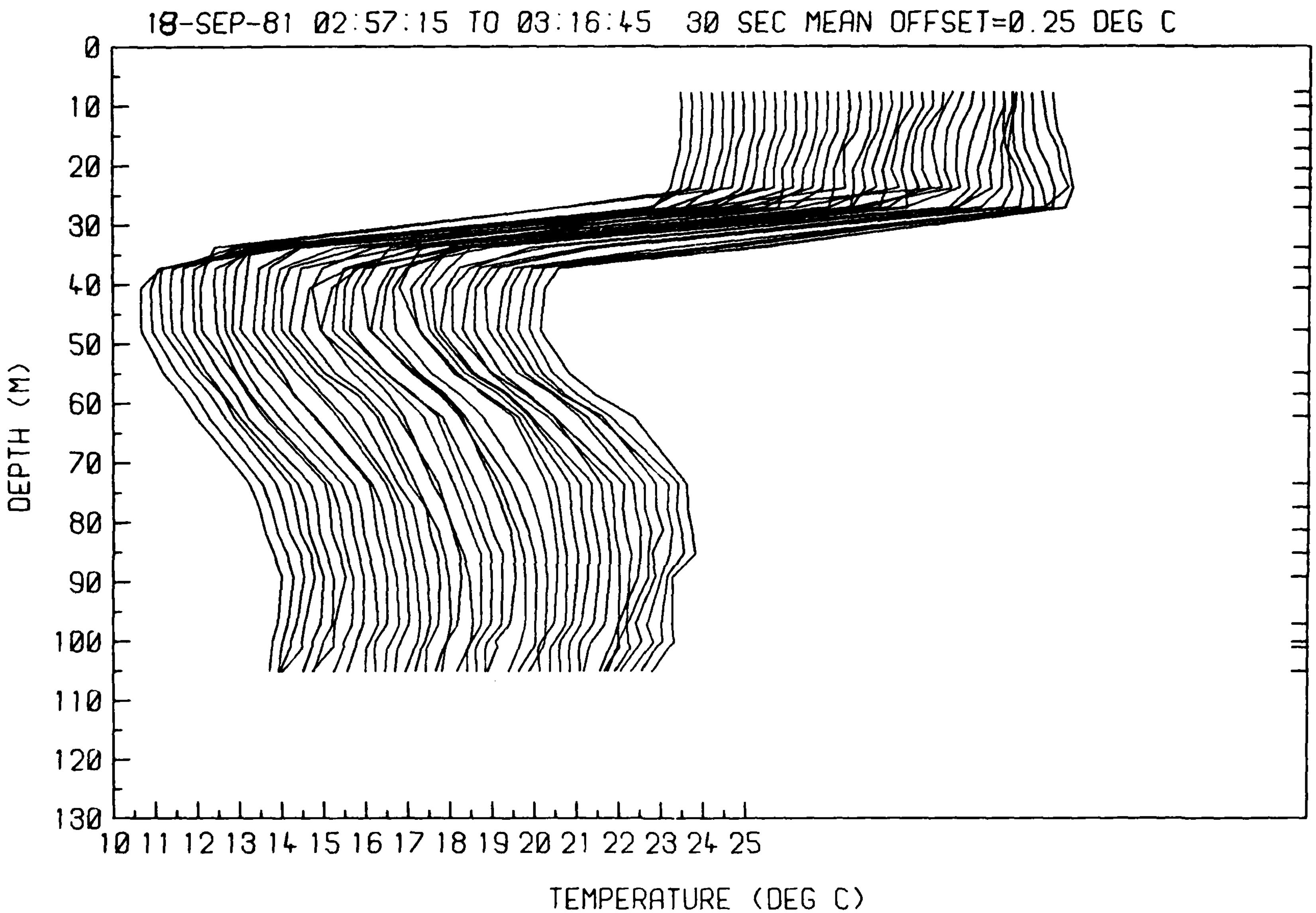

Figure 7. Sequential 30-s averaged temperature profiles at the edge of a warm core ring.

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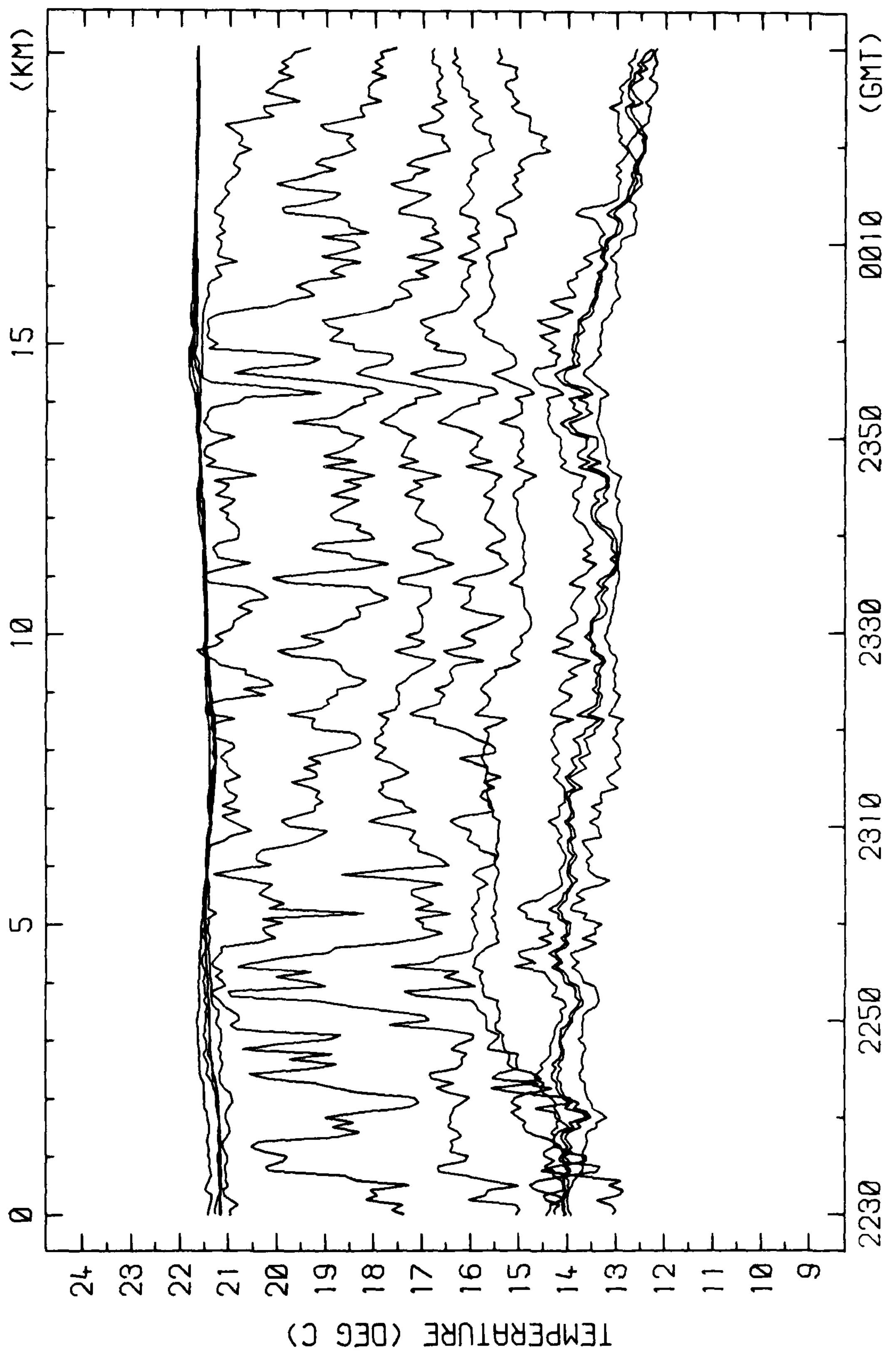
APPENDIX A

Temperature Cross-Sections

On the following pages there are plots, one for each two-hour period from the beginning of each run, of temperature measurements as a function of time and distance along the tow. The operating temperature sensors and their mean depths are given in Table 1. The latitude and longitude at the beginning of each two-hour period is given in Table 2 together with distance travelled and the direction and speed of the tow. The temperature measurements were low-pass filtered by averaging over sequential 30-s intervals. Because of kiting of the towed chain, some of the fluctuations in temperature are caused by fluctuations of the depth of the thermistors.



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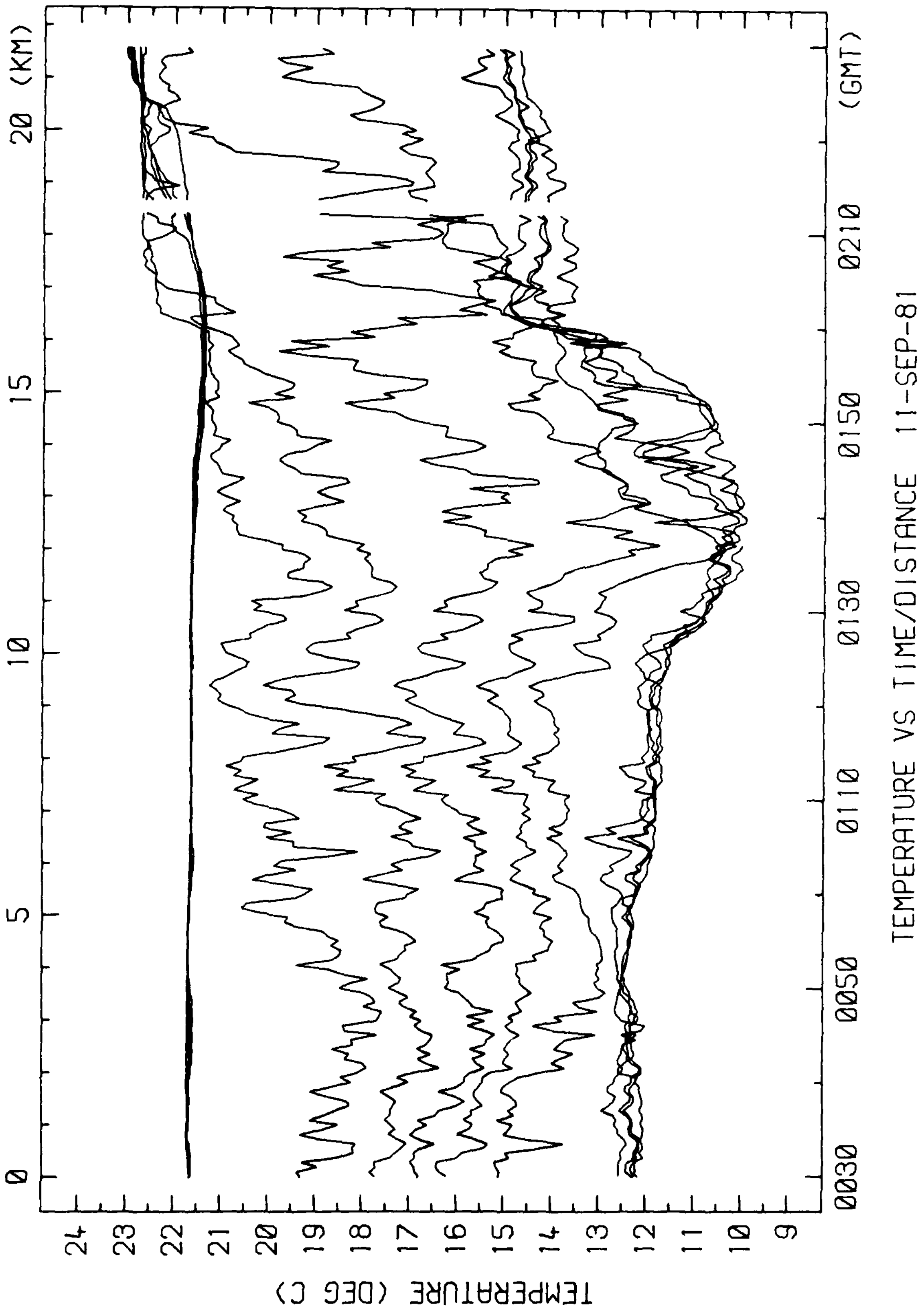
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0 5 10 15 20 (KM)
0030 0050 0110 0130 0150 0210 (GMT)
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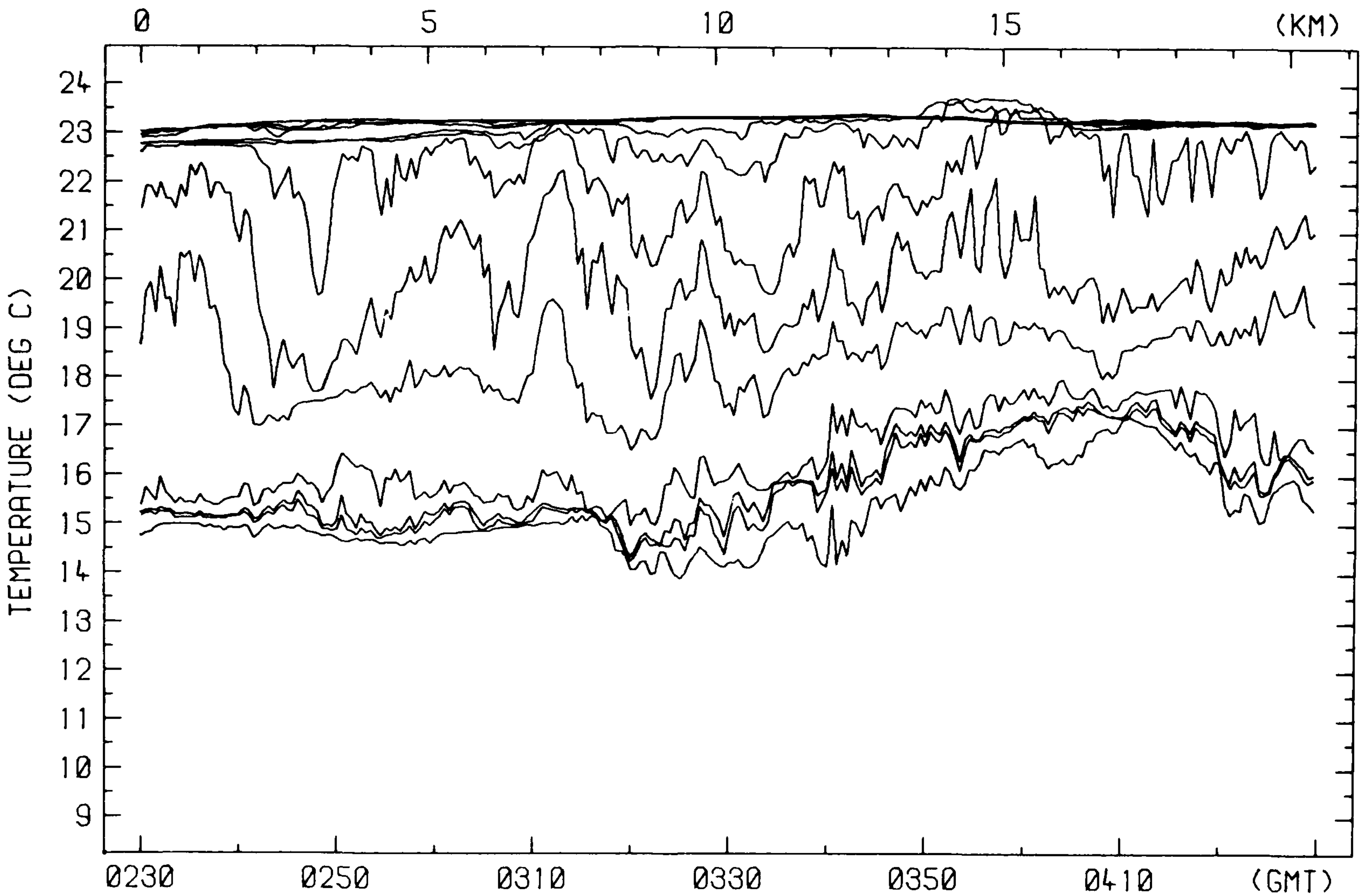

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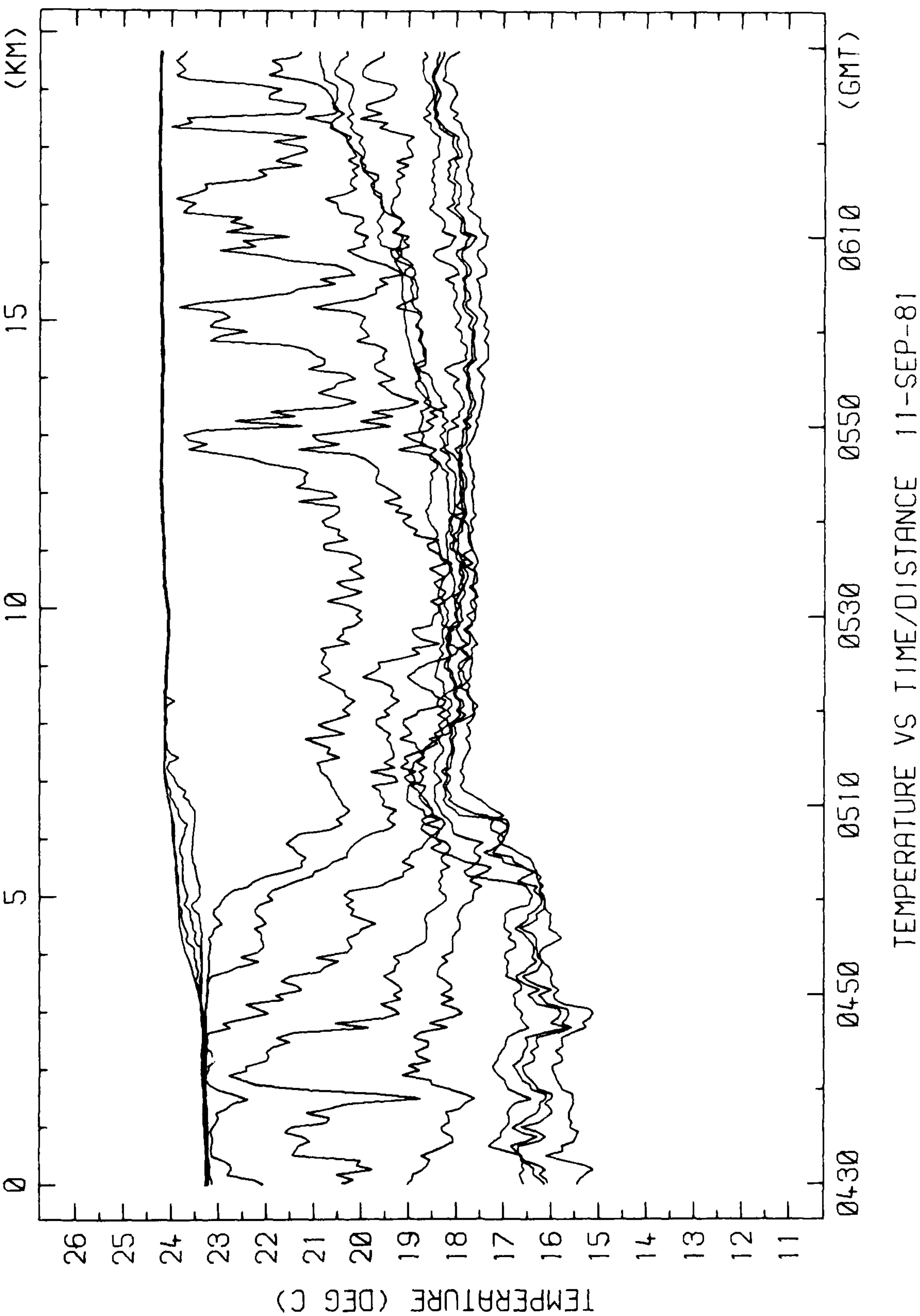
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TEMPERATURE (DEG C)
(KM)
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(GMT)
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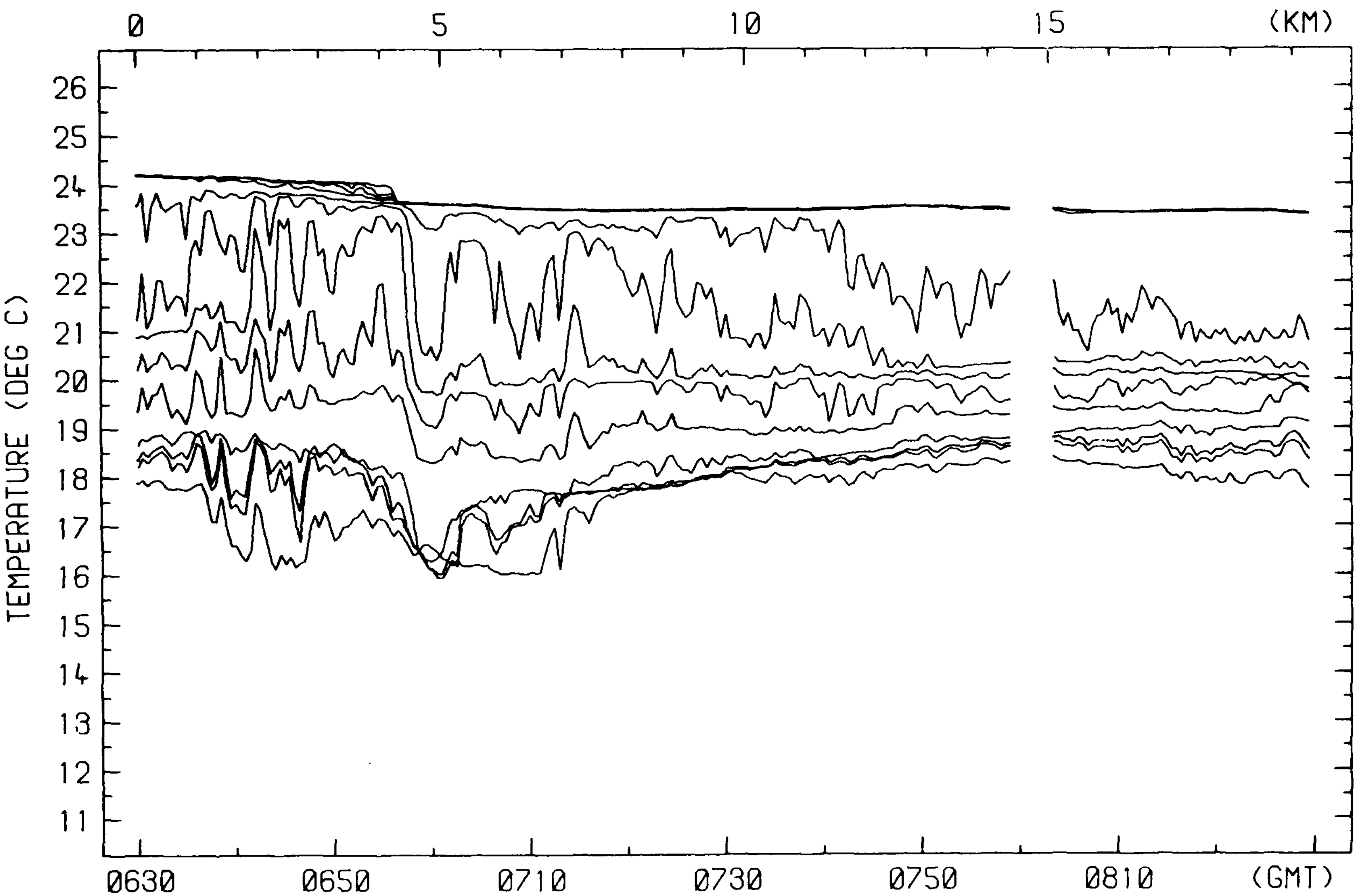

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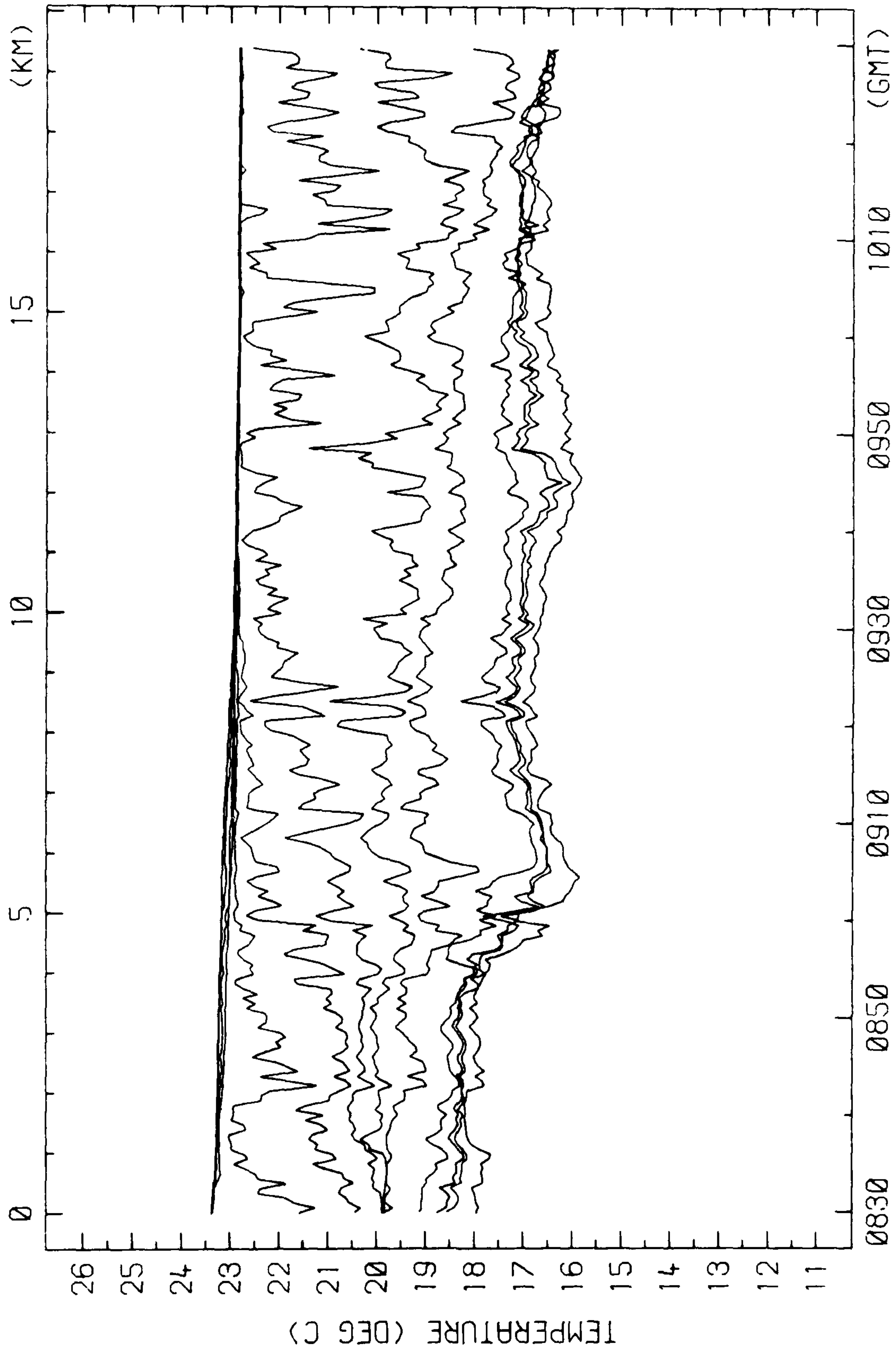

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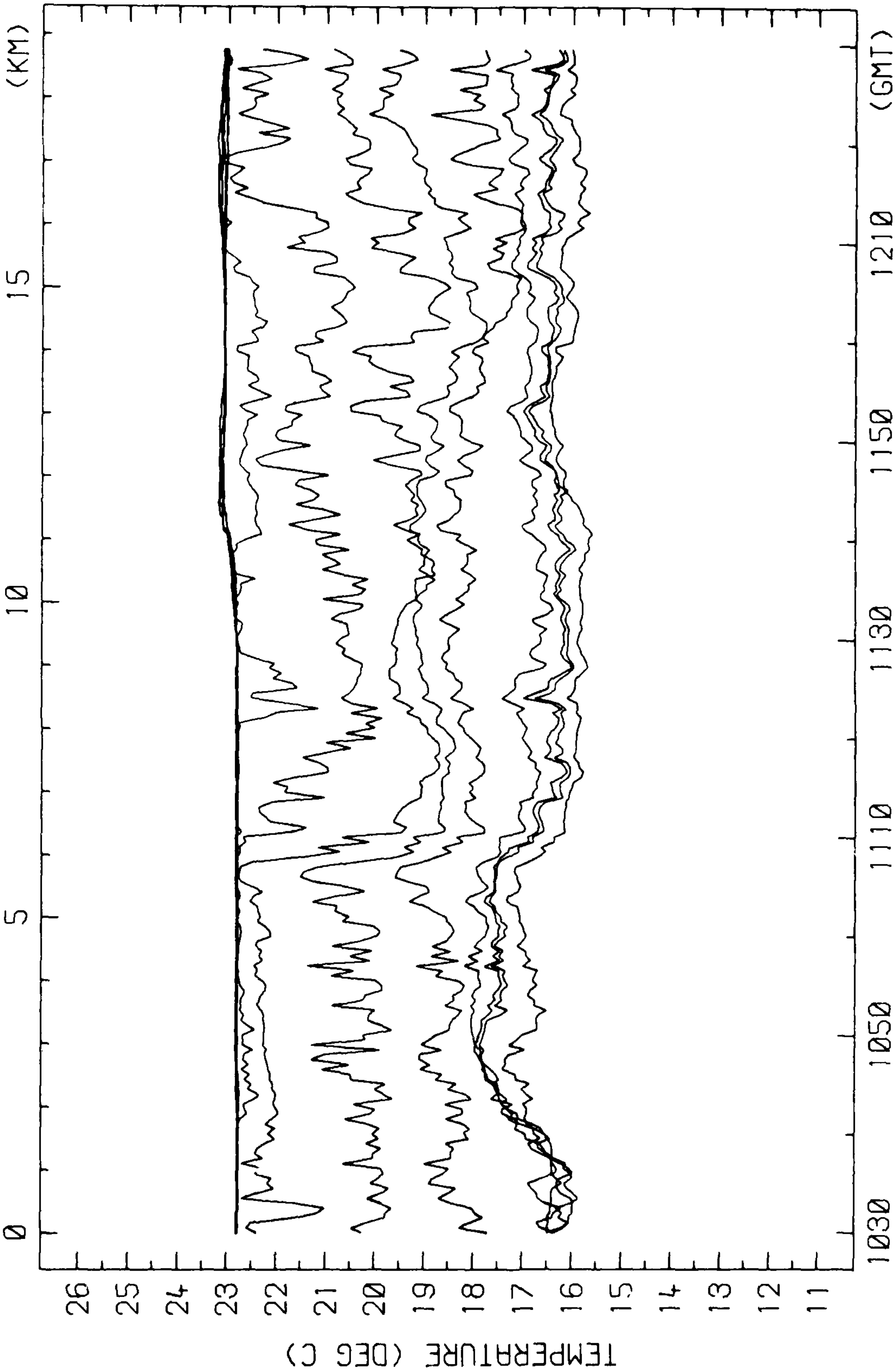

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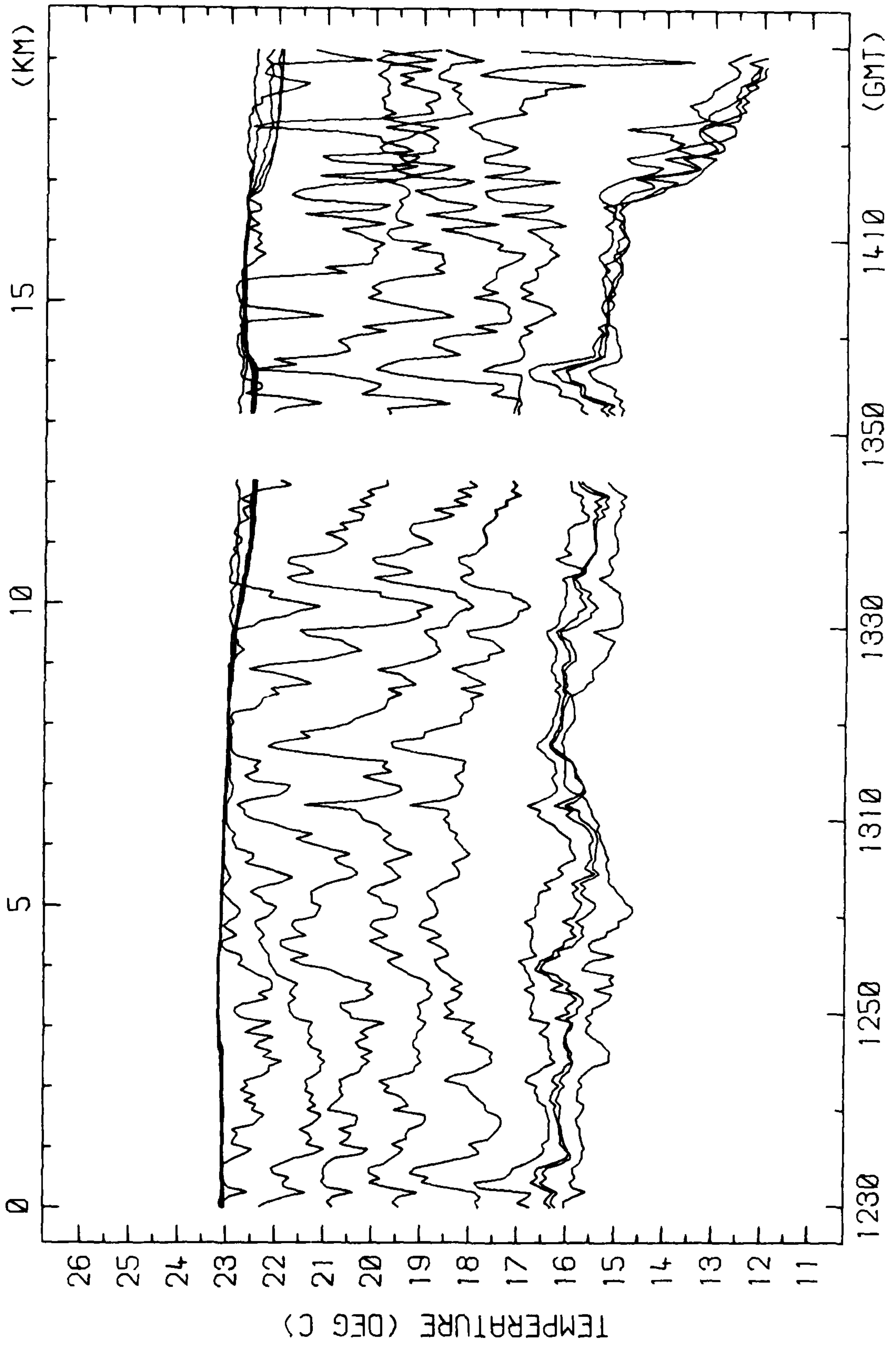

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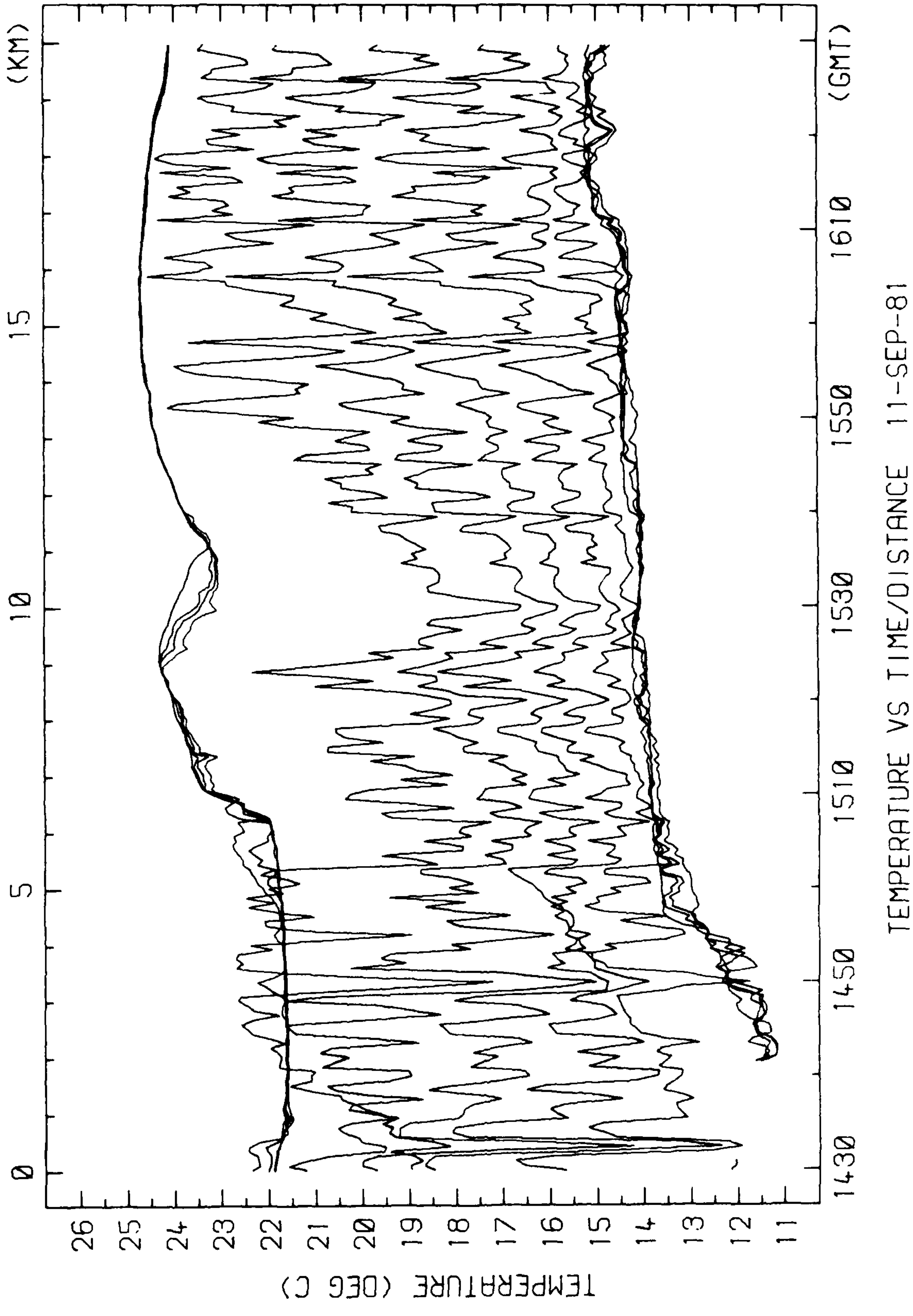
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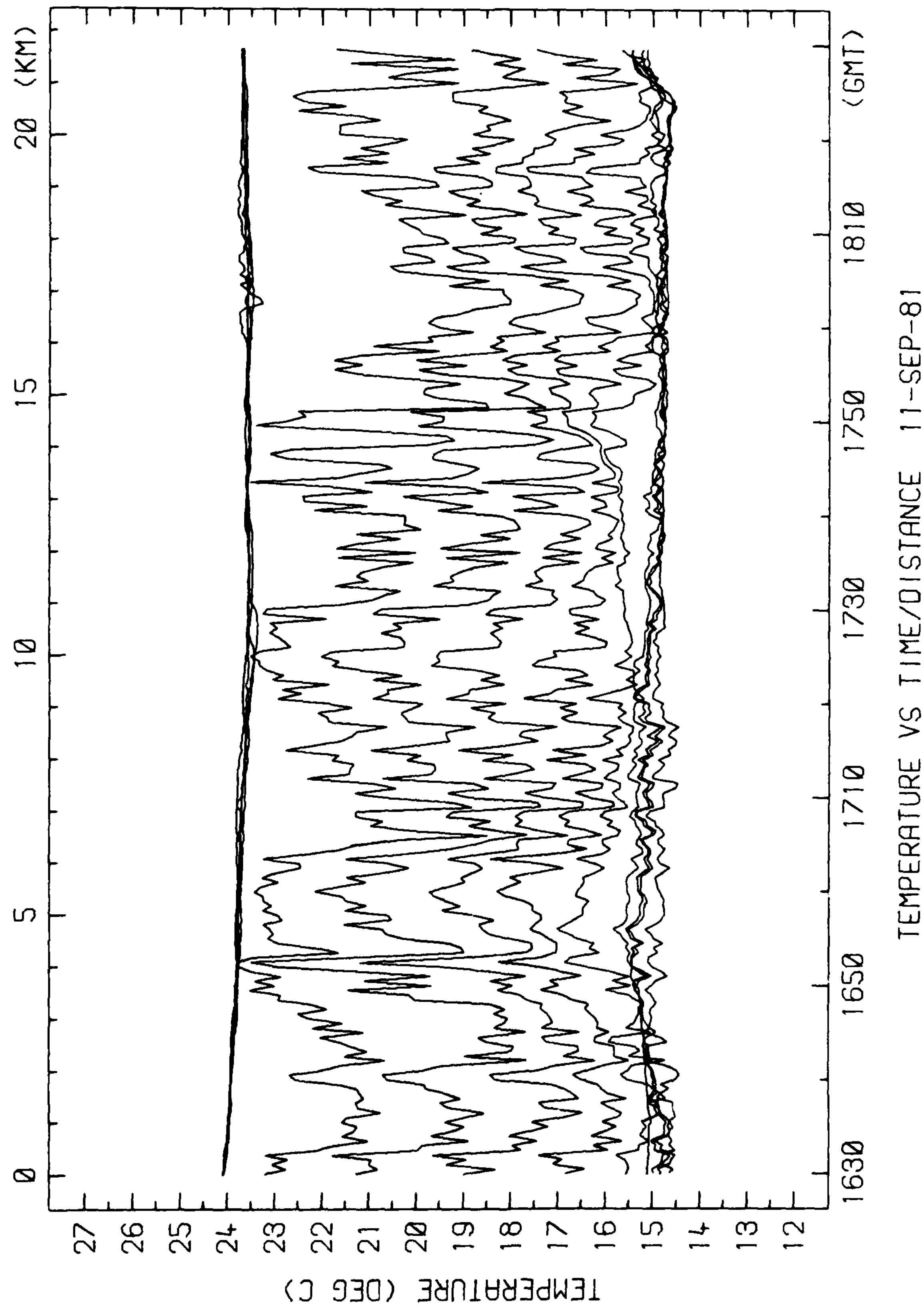

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(GMT)
TEMPERATURE VS TIME/DISTANCE 11-SEP-81
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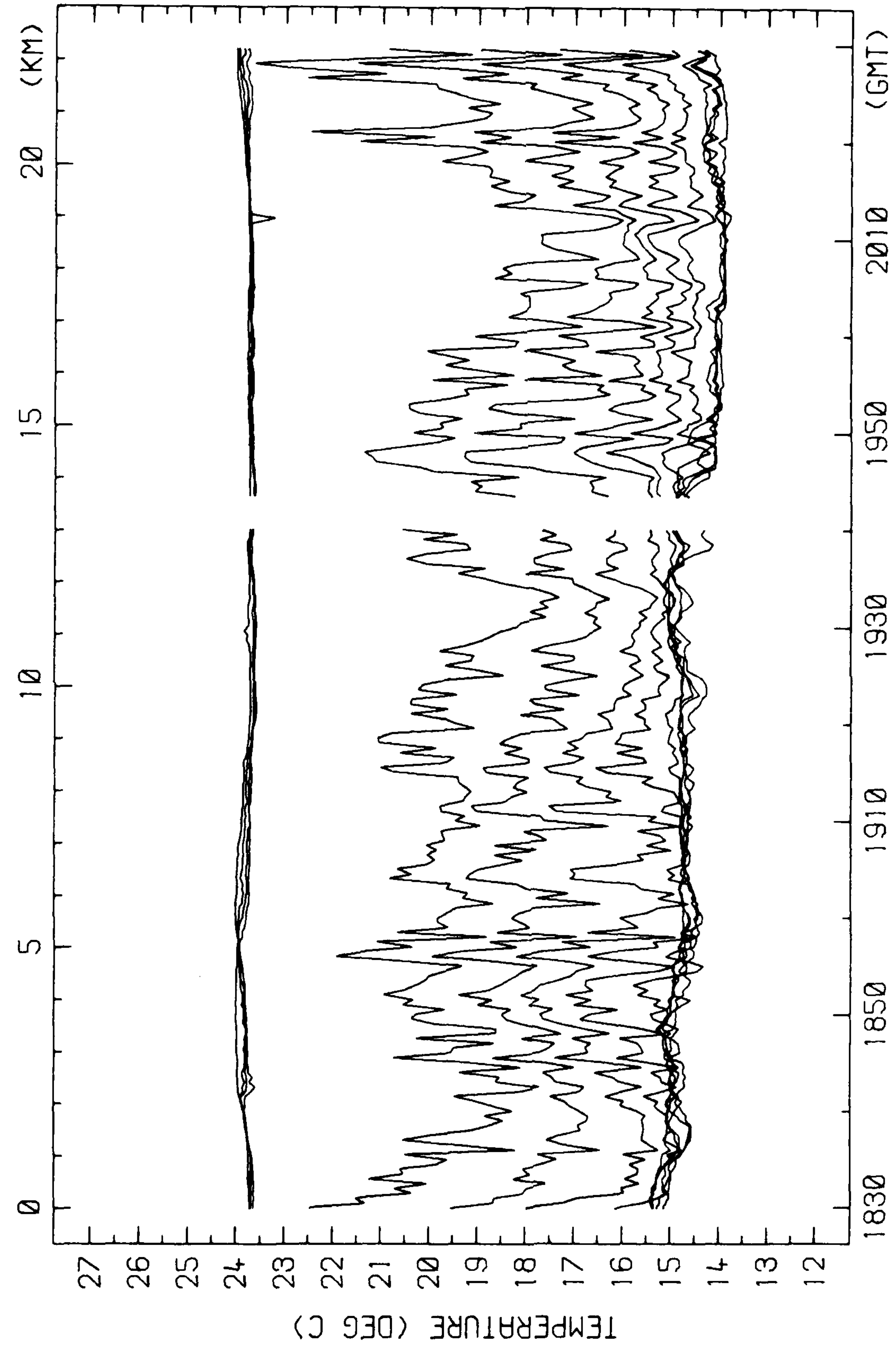

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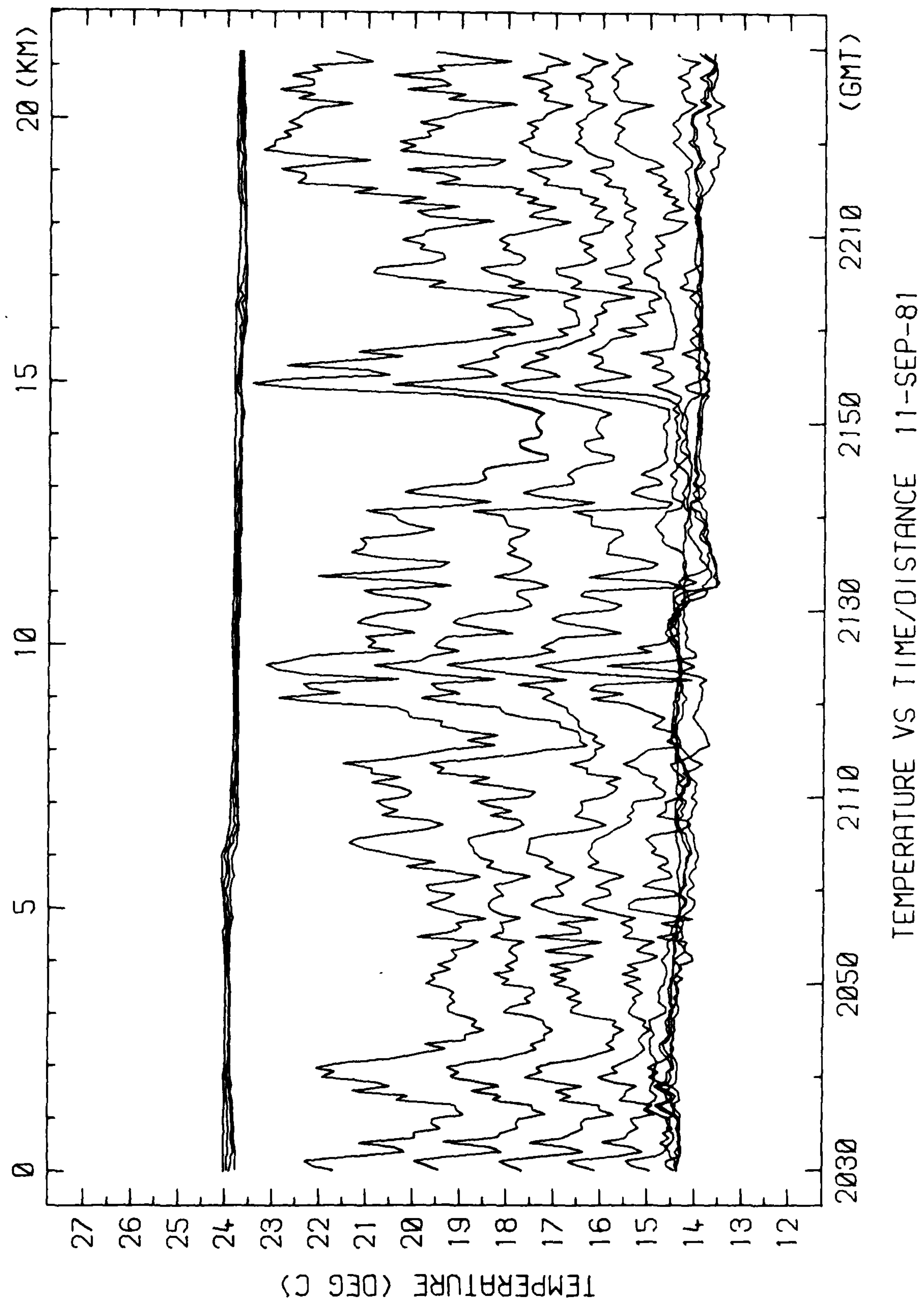
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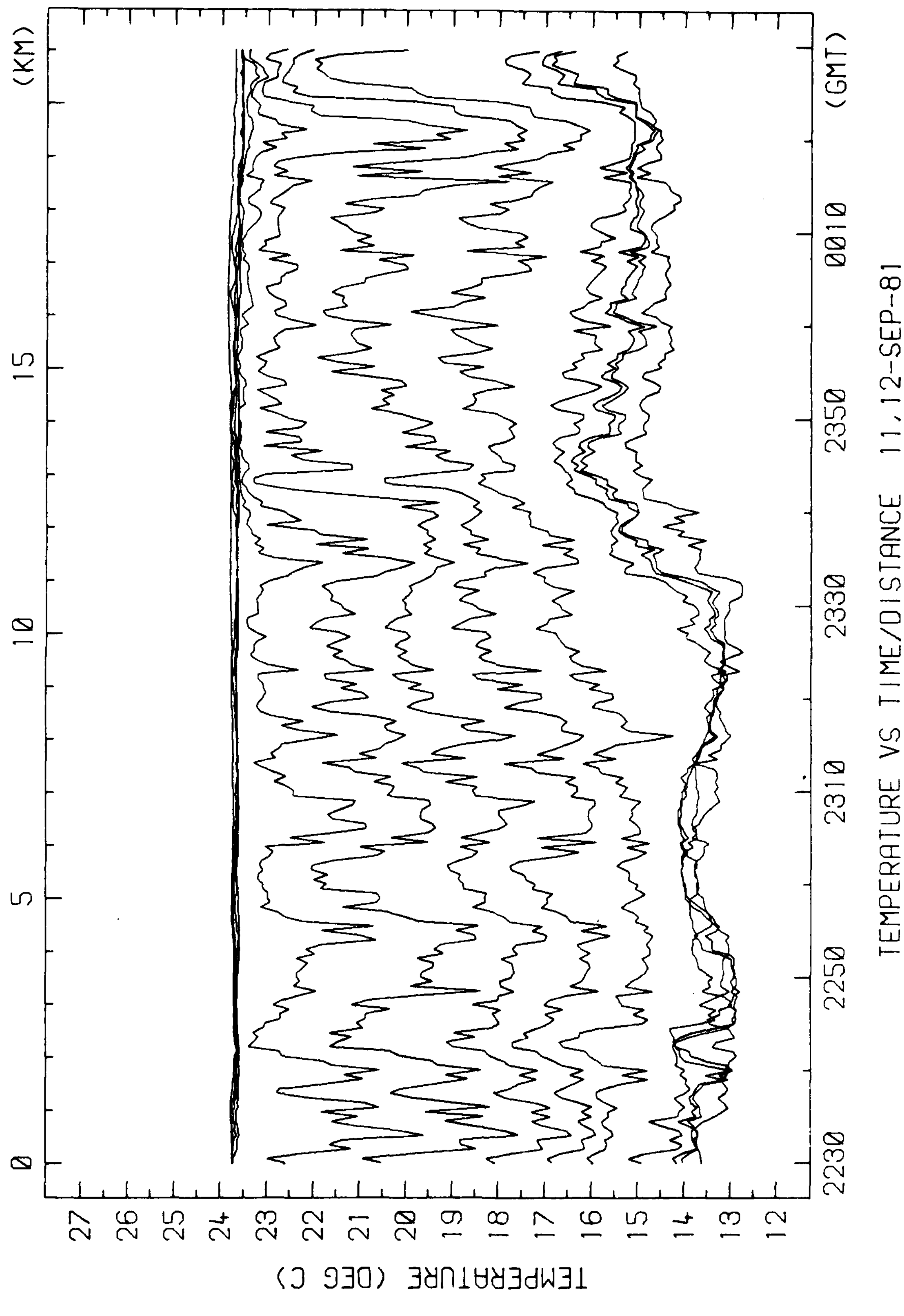
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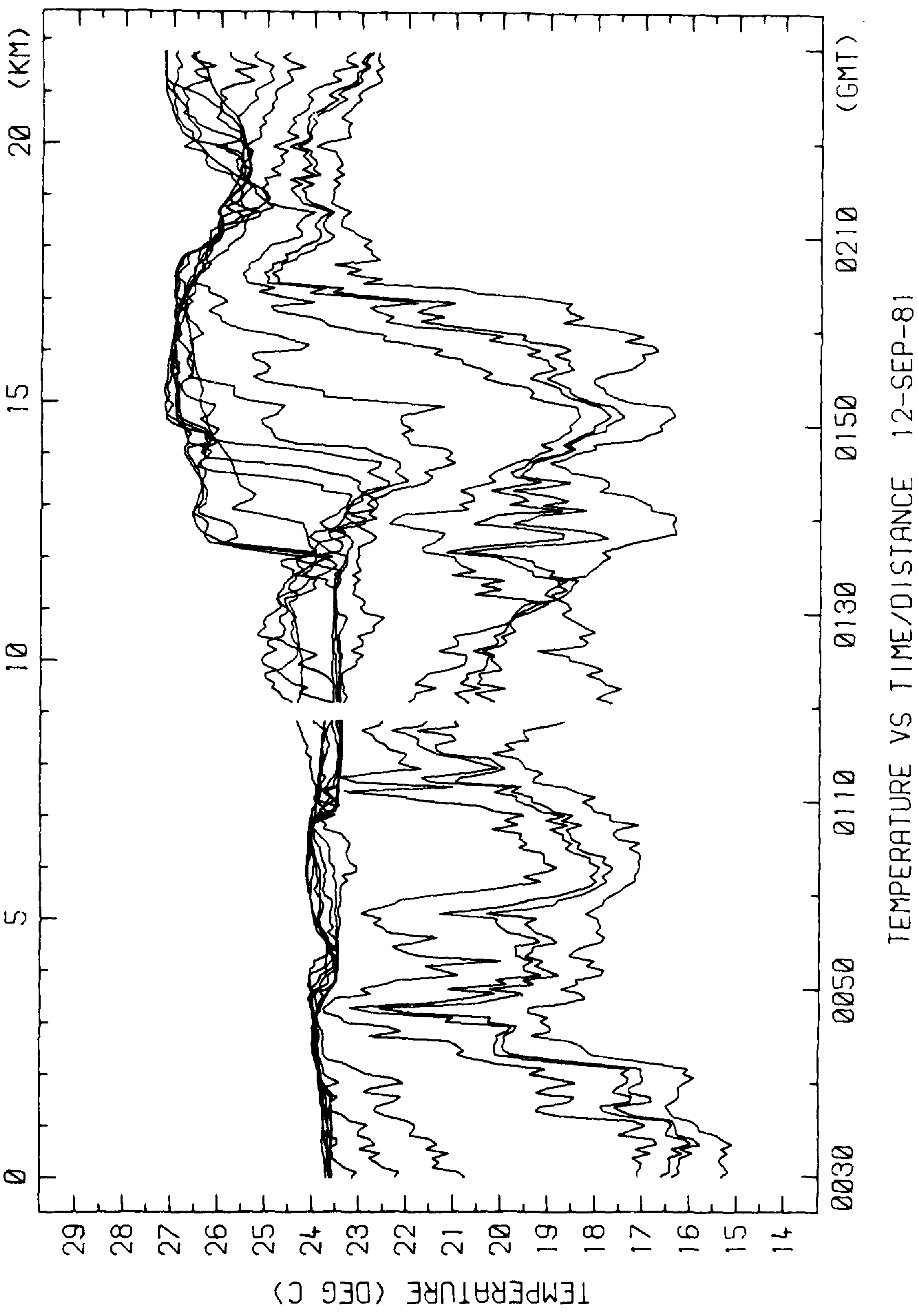
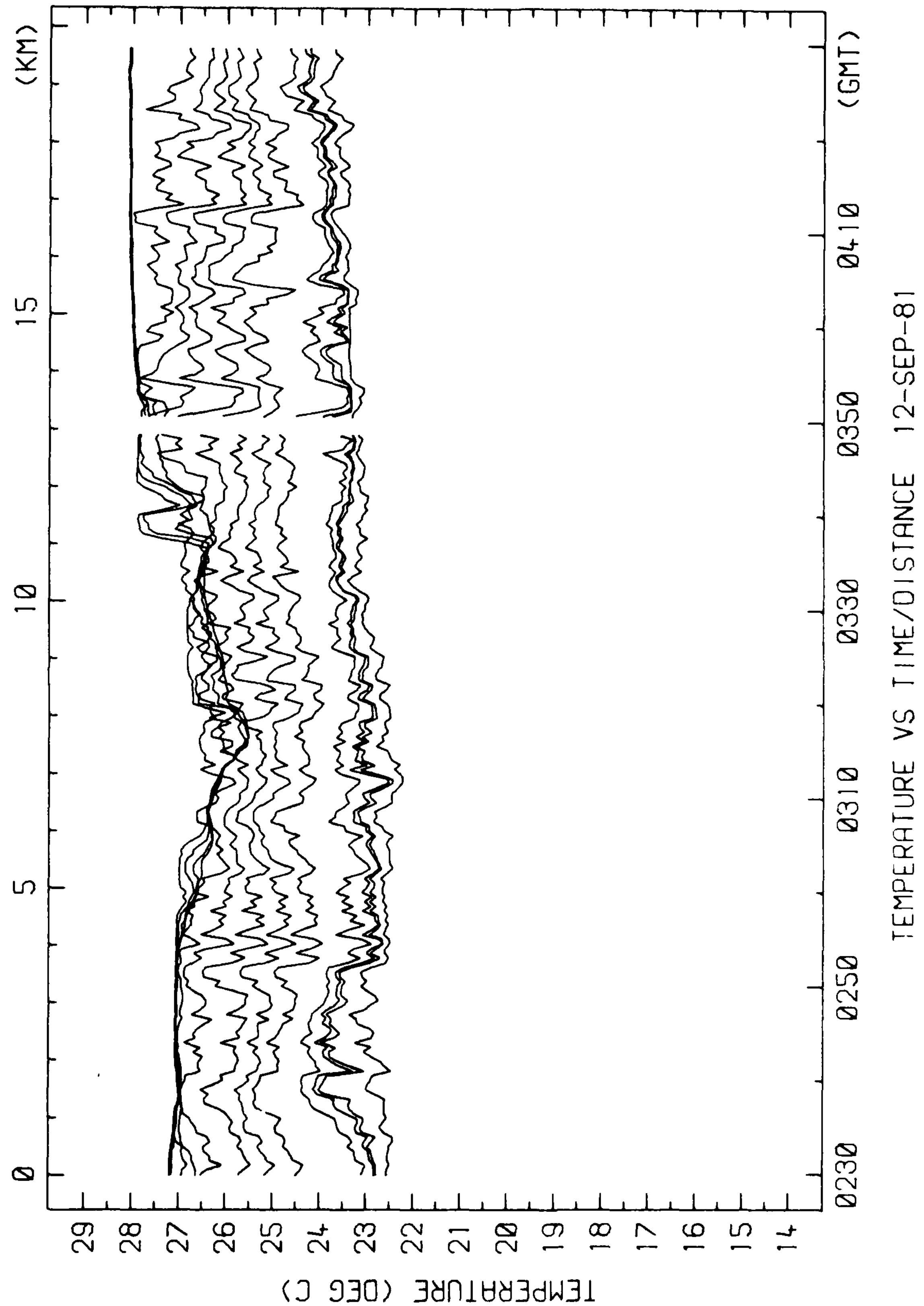
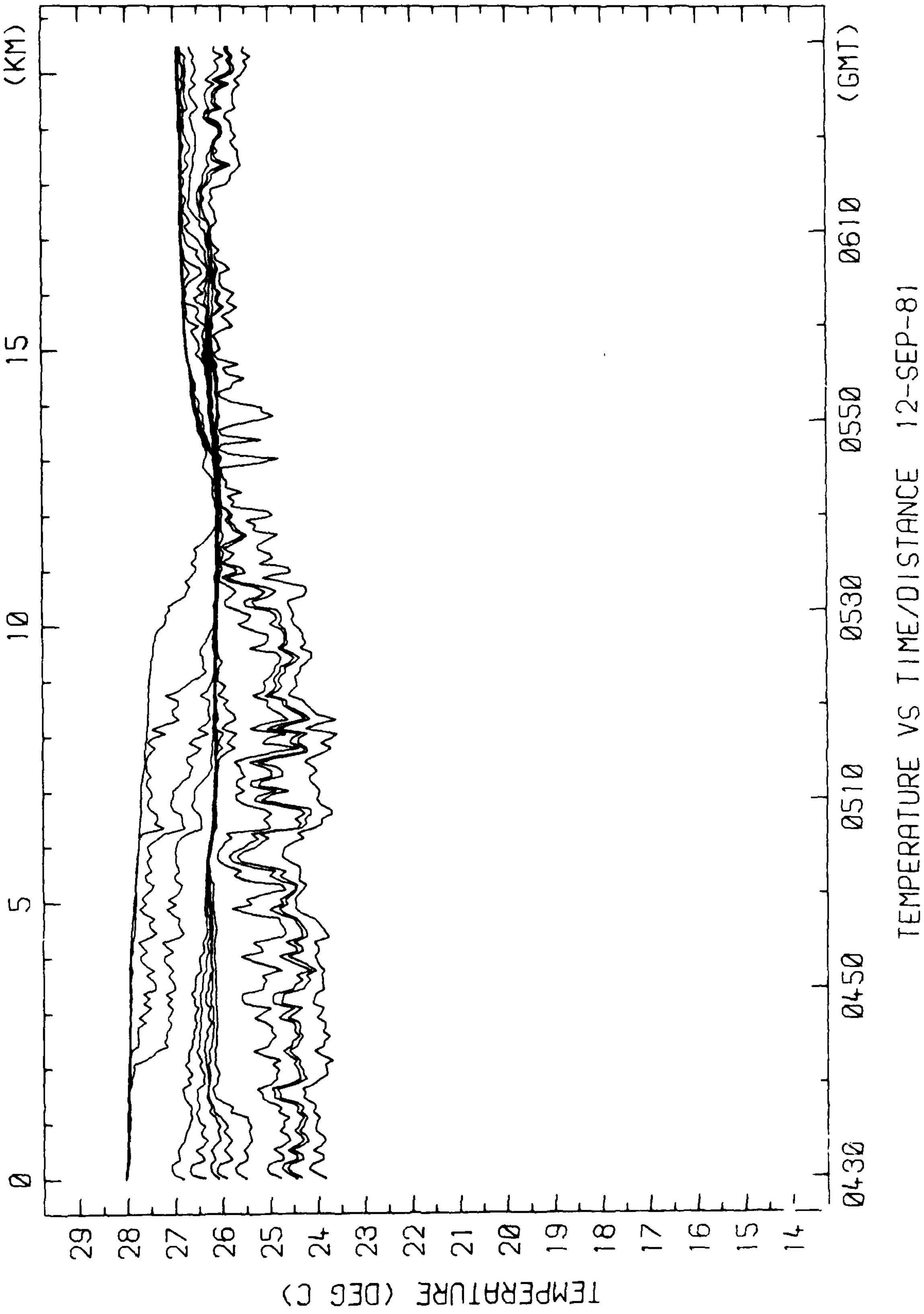
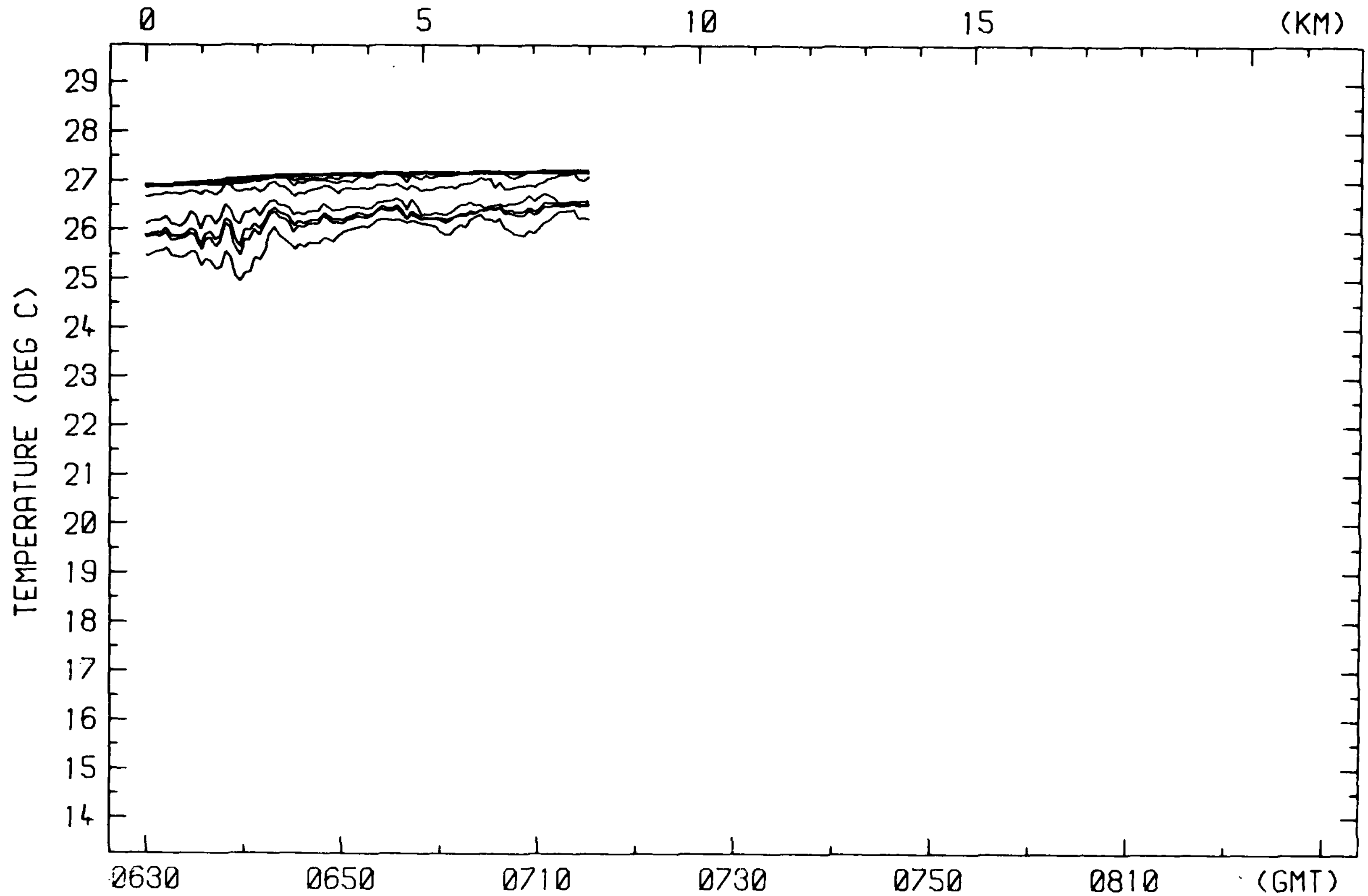
26
27

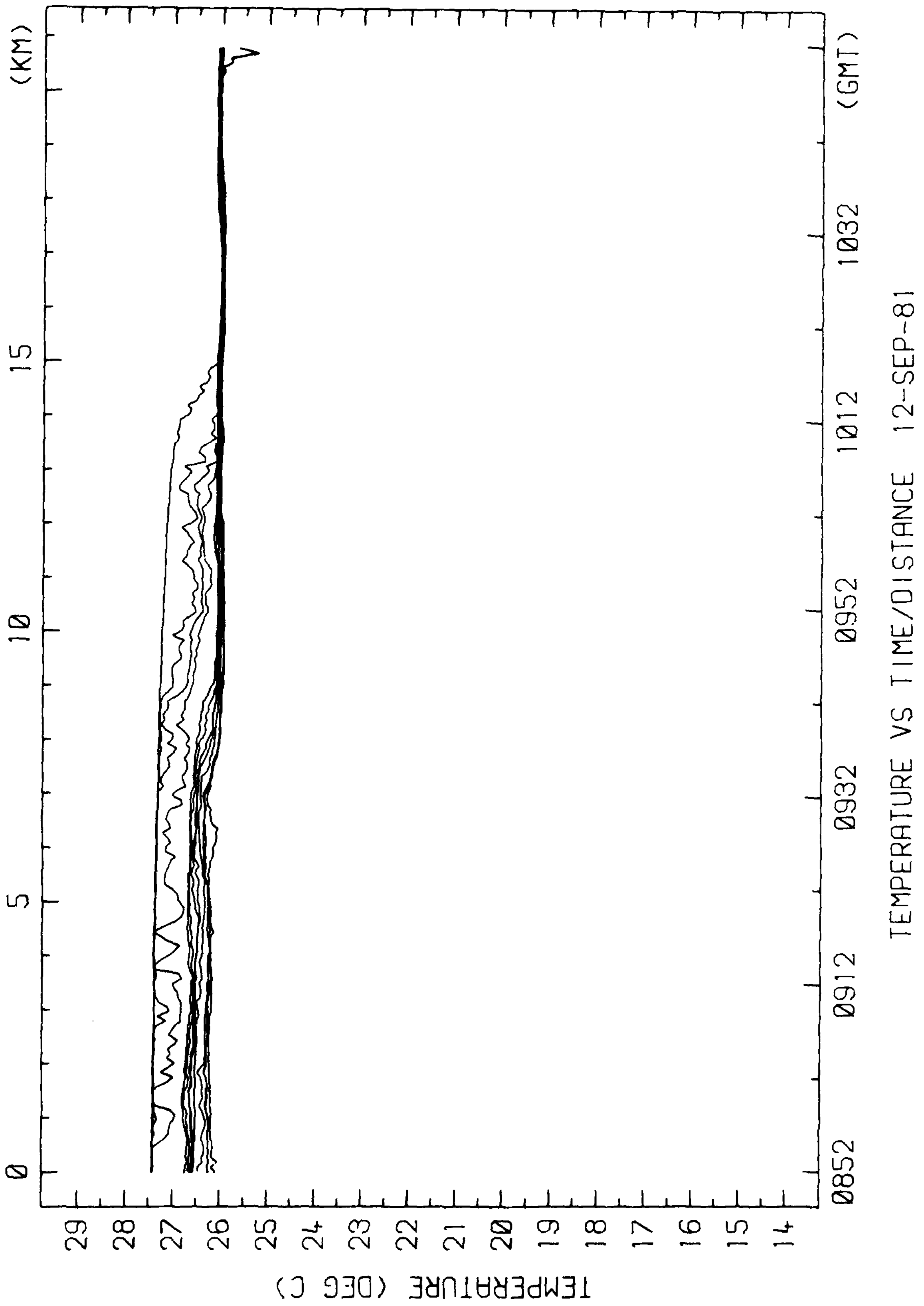

0
5
10
15
20
(KM)
0030
0050
0110
0130
0150
0210
(GMT)
TEMPERATURE VS TIME/DISTANCE 12-SEP-81
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
TEMPERATURE (DEG C)

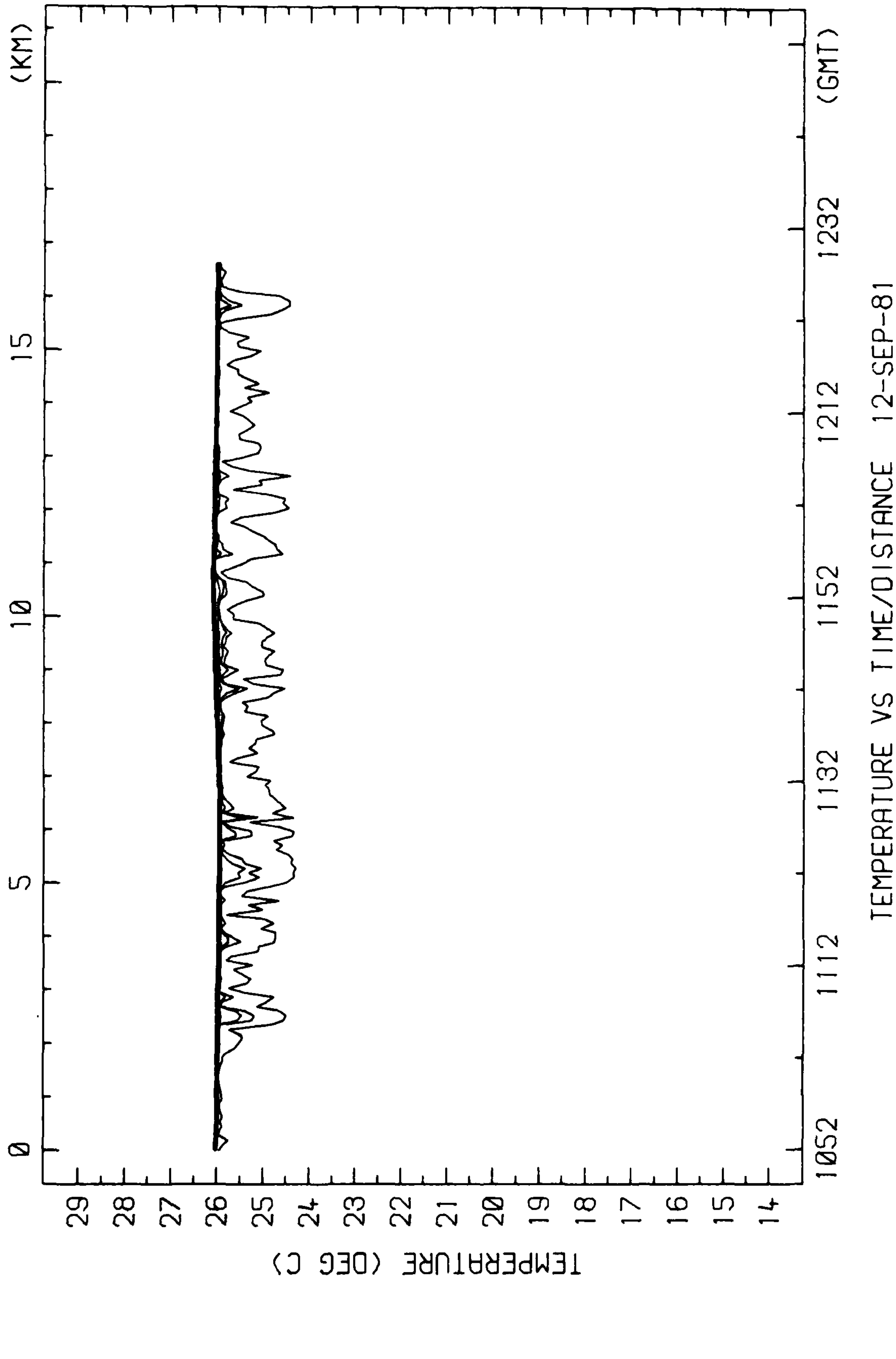

TEMPERATURE VS TIME/DISTANCE 12-SEP-81
TEMPERATURE (DEG C)
(KM)
(GMT)
0
5
10
15
0230
0250
0310
0330
0350
0410
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14

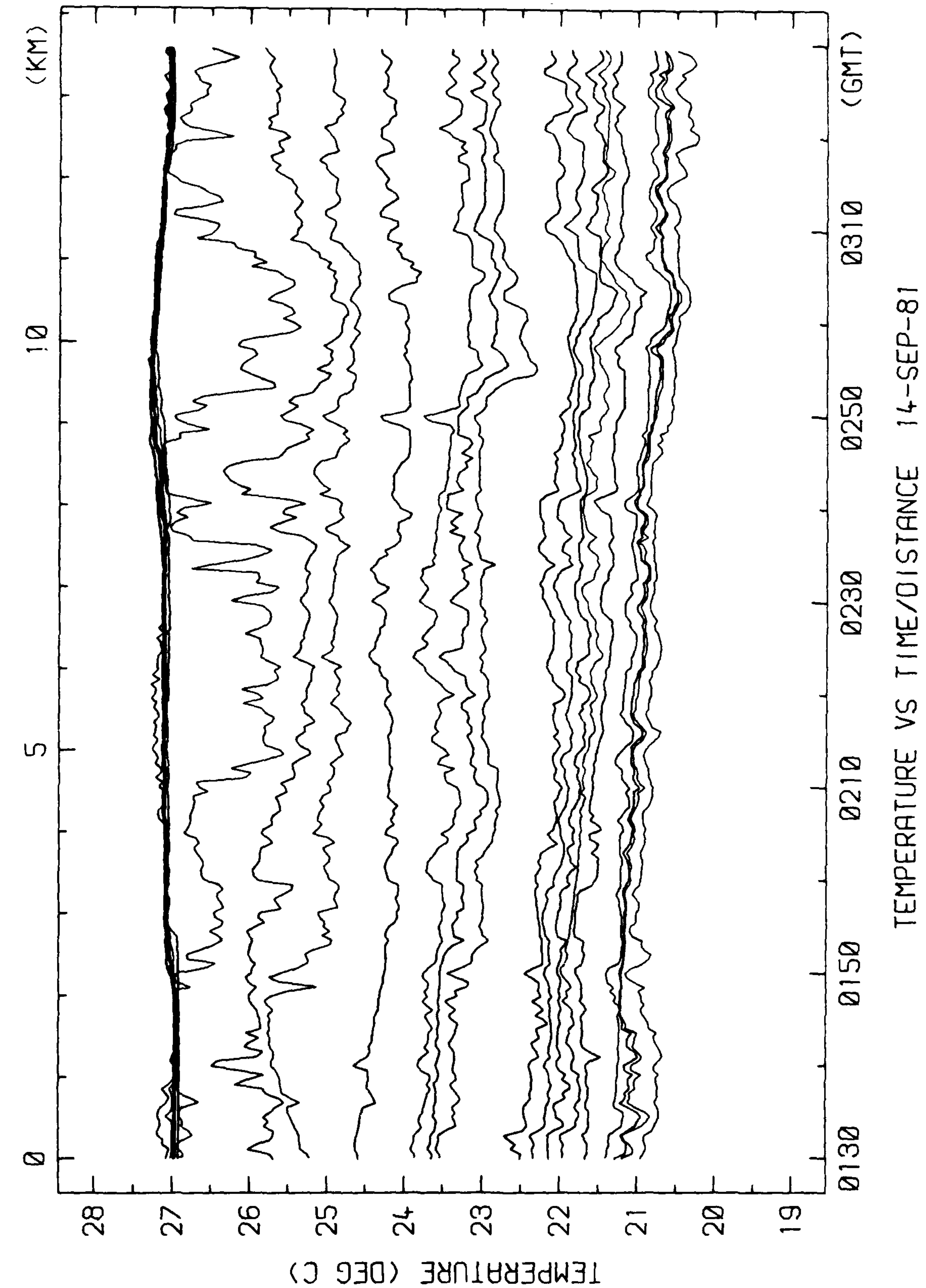

TEMPERATURE VS TIME/DISTANCE 12-SEP-81
TEMPERATURE (DEG C)
(KM)
Ø
5
1Ø
15
(GMT)
Ø43Ø
Ø45Ø
Ø51Ø
Ø53Ø
Ø55Ø
Ø61Ø
29
28
27
26
25
24
23
22
21
2Ø
19
18
17
16
15
14

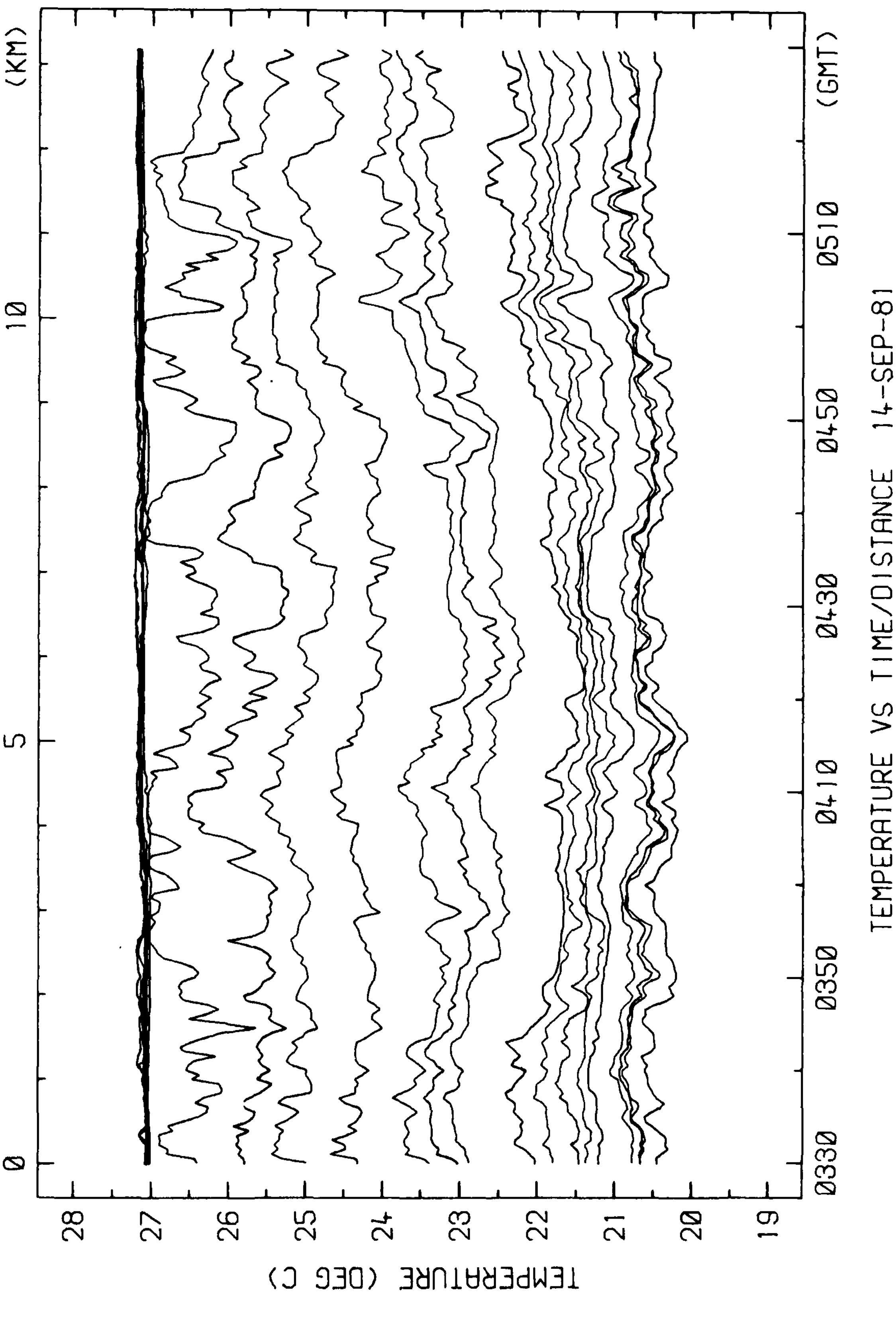


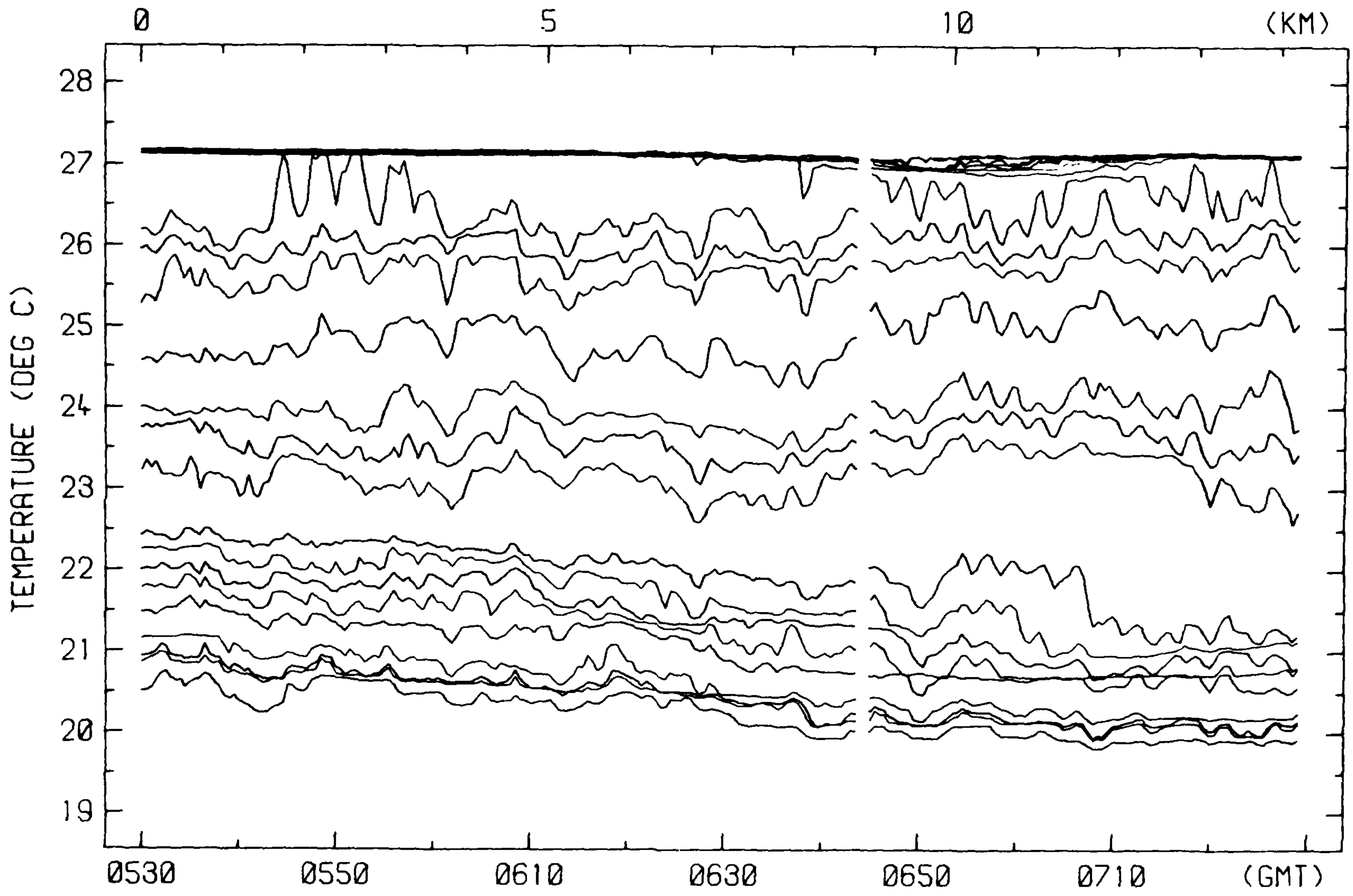
TEMPERATURE VS TIME/DISTANCE 12-SEP-81


(KM)
0
5
10
15
0852
0912
0932
0952
1012
1032
(GMT)
TEMPERATURE VS TIME/DISTANCE 12-SEP-81
TEMPERATURE (DEG C)
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14

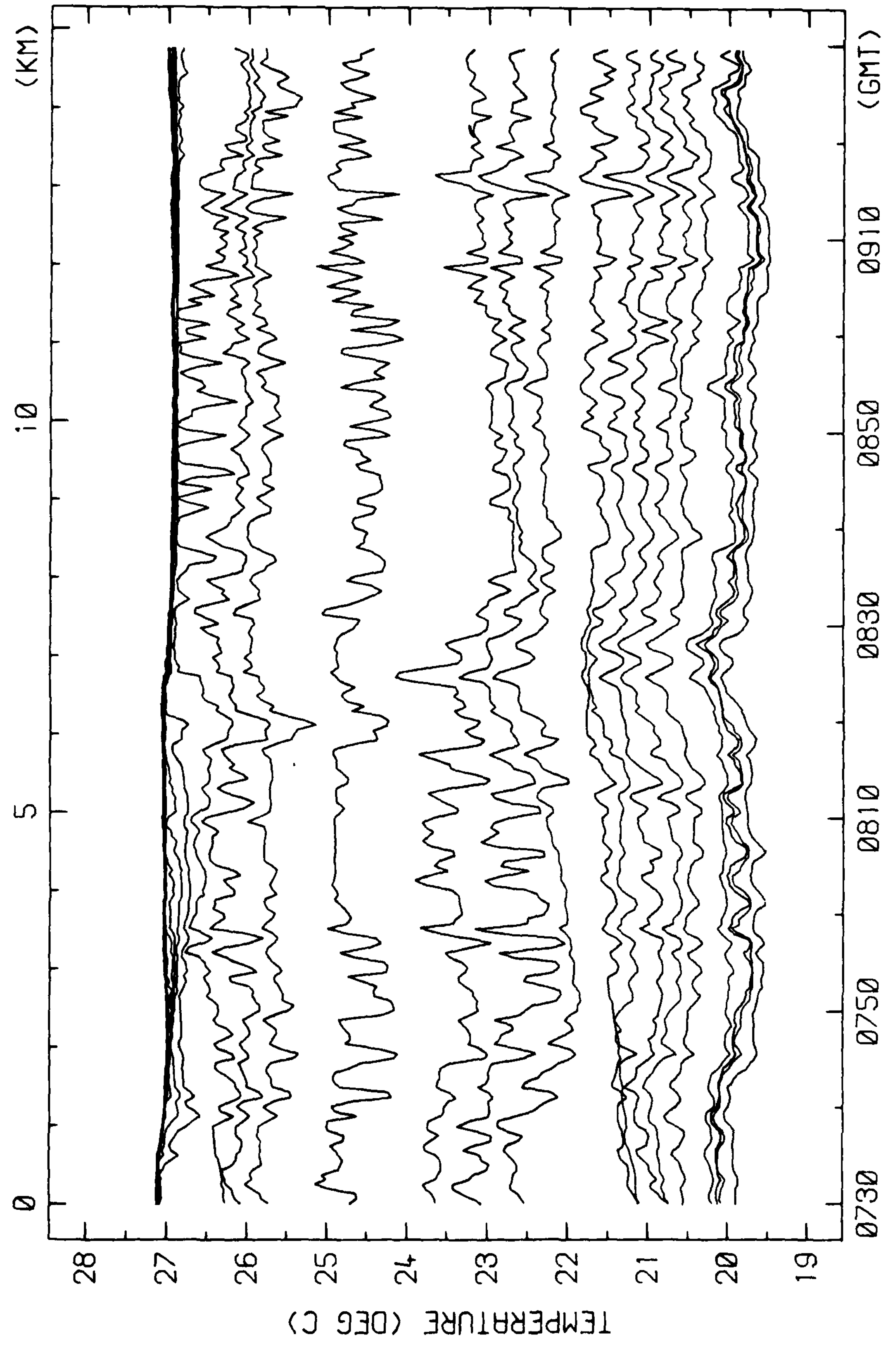

TEMPERATURE VS TIME/DISTANCE 12-SEP-81
TEMPERATURE (DEG C)
29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14
0 5 10 15 (KM)
1052 1112 1132 1152 1212 1232 (GMT)


TEMPERATURE VS TIME/DISTANCE 14-SEP-81
TEMPERATURE (DEG C)
28
27
26
25
24
23
22
21
20
19
0
5
10
(KM)
0130
0150
0210
0230
0250
0310
(GMT)

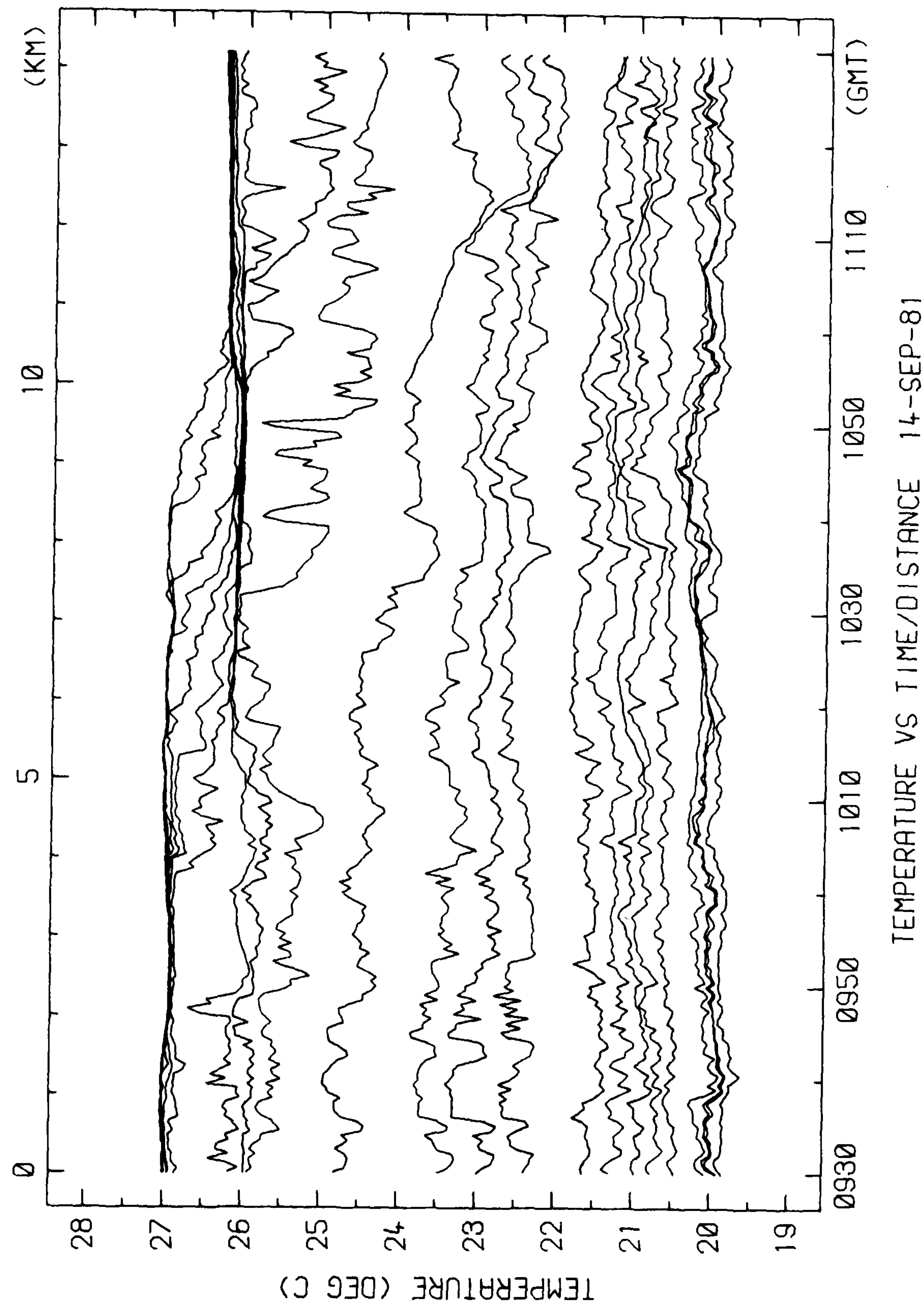

TEMPERATURE VS TIME/DISTANCE 14-SEP-81
TEMPERATURE (DEG C)
28
27
26
25
24
23
22
21
20
19
0
5
10
(KM)
0330
0350
0410
0430
0450
0510
(GMT)

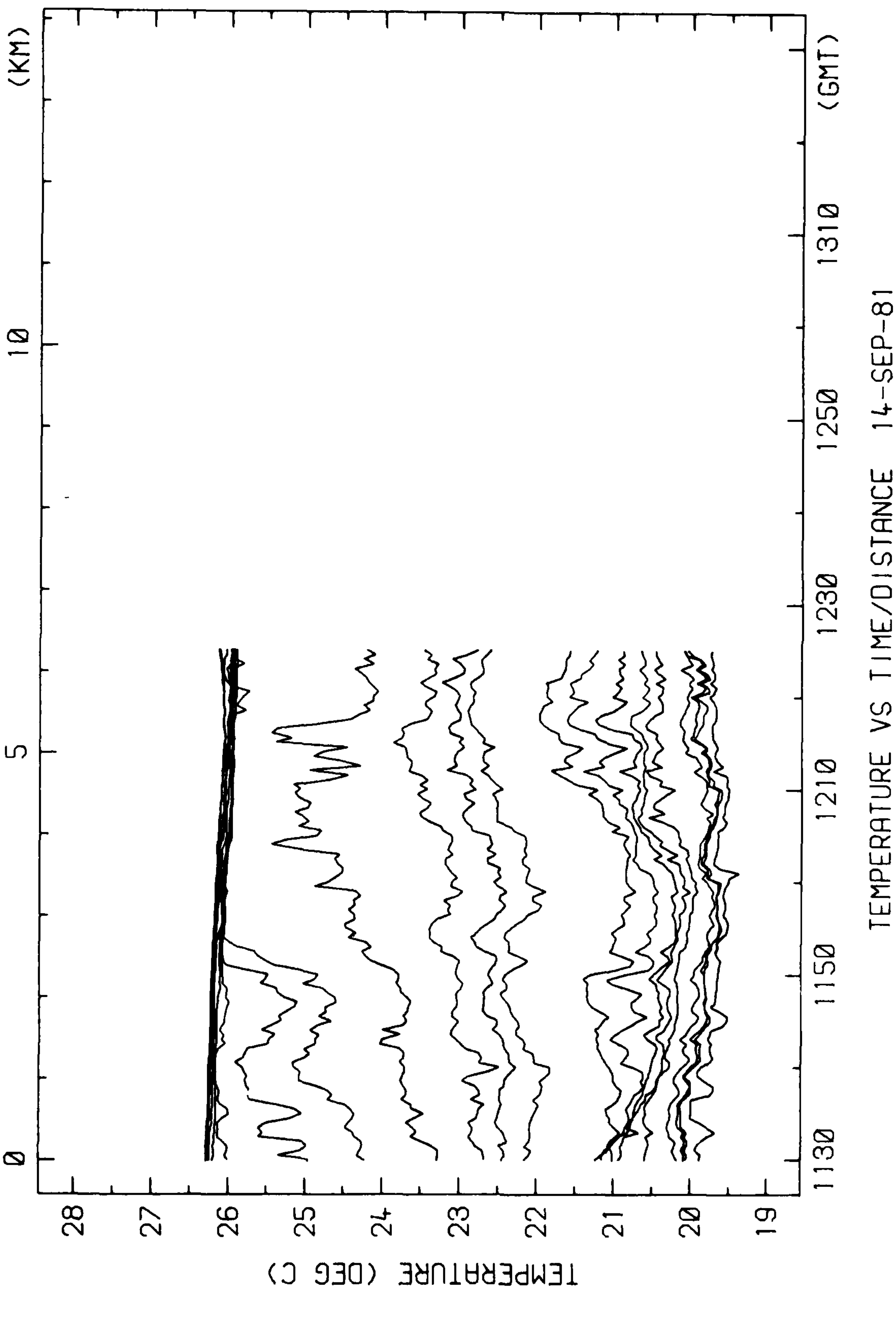


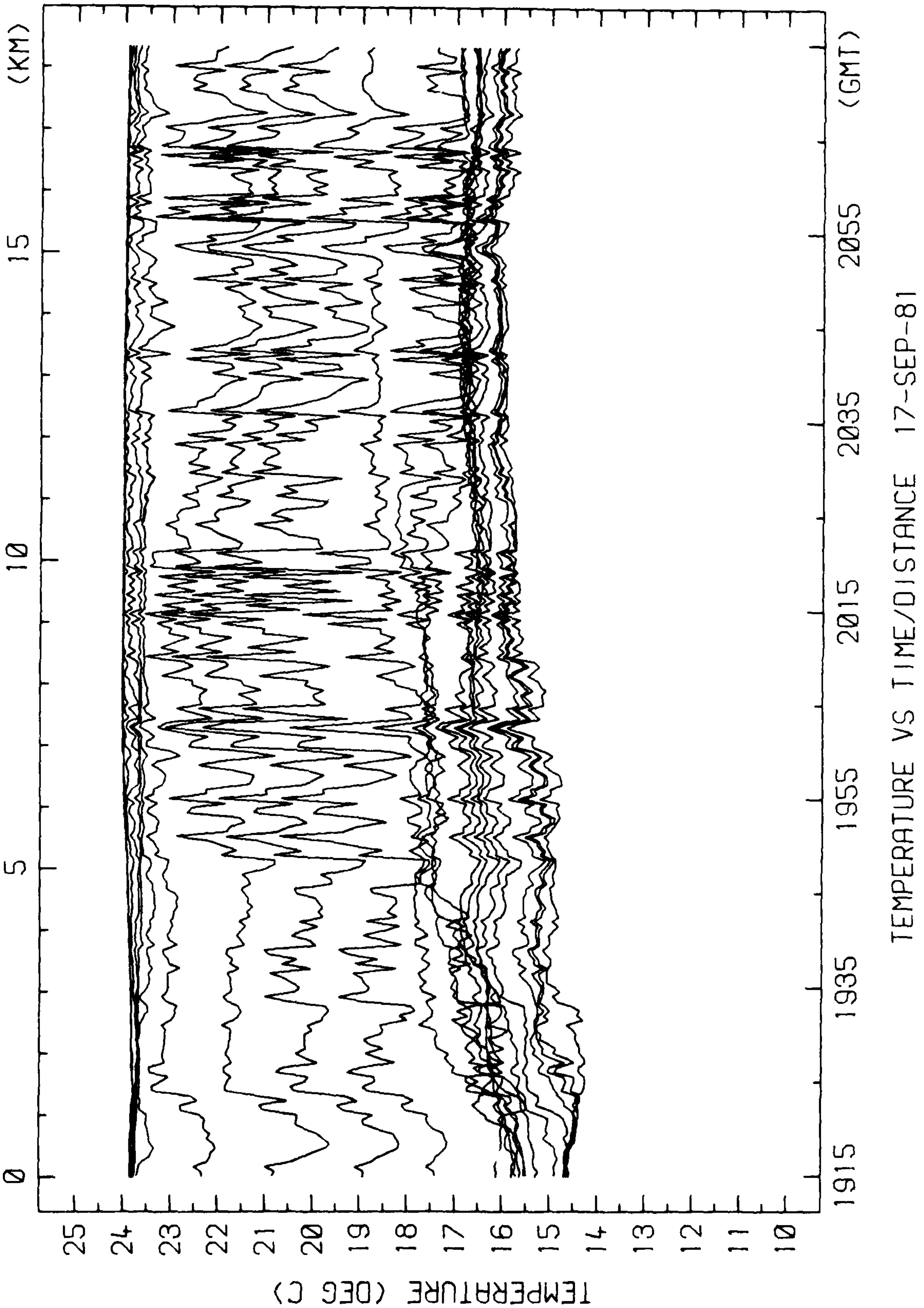
TEMPERATURE VS TIME/DISTANCE 14-SEP-81



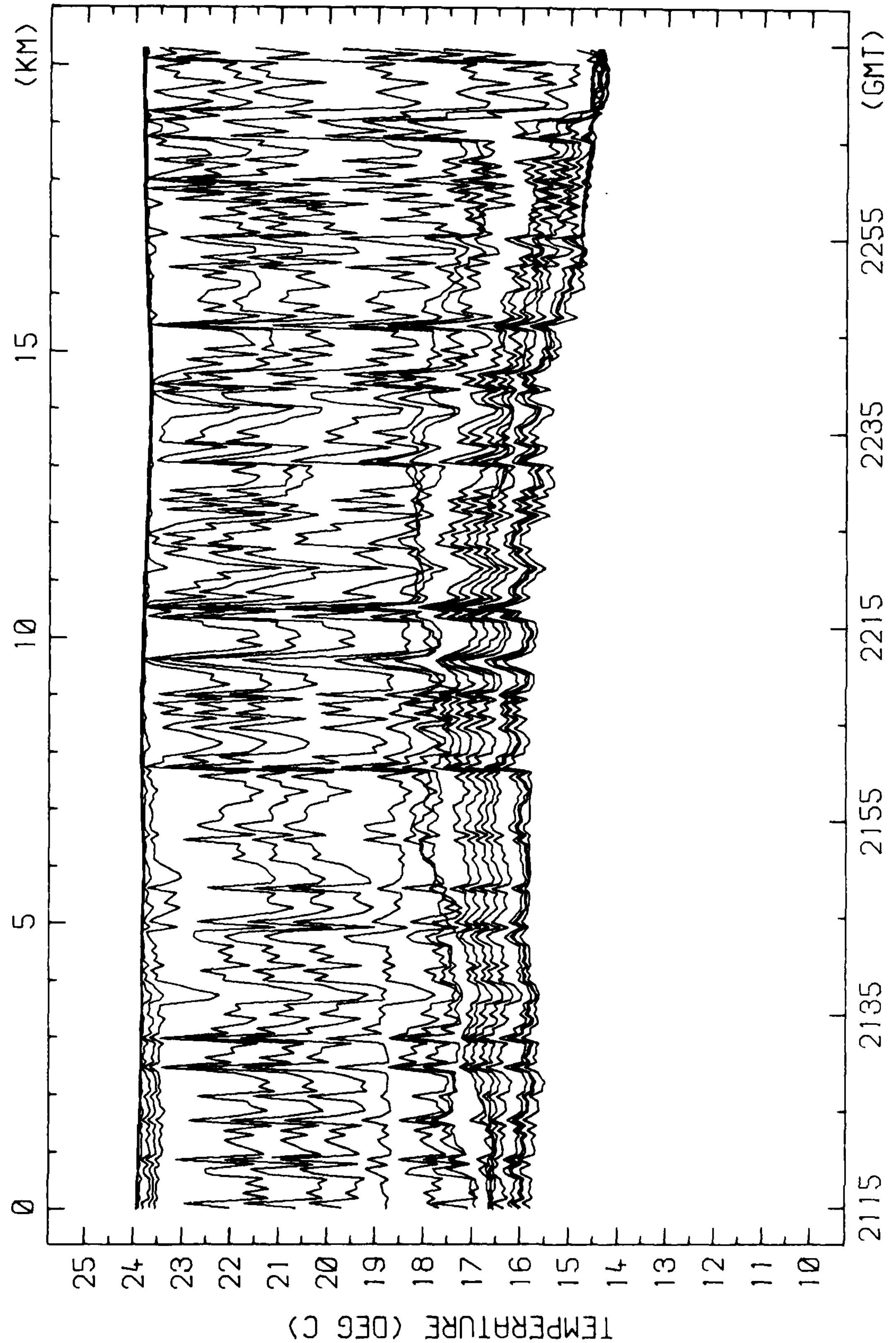
TEMPERATURE VS TIME/DISTANCE 14-SEP-81


TEMPERATURE (DEG C)
28
27
26
25
24
23
22
21
20
19
0
5
10
(KM)
0930
0950
1010
1030
1050
1110
(GMT)
TEMPERATURE VS TIME/DISTANCE 14-SEP-81

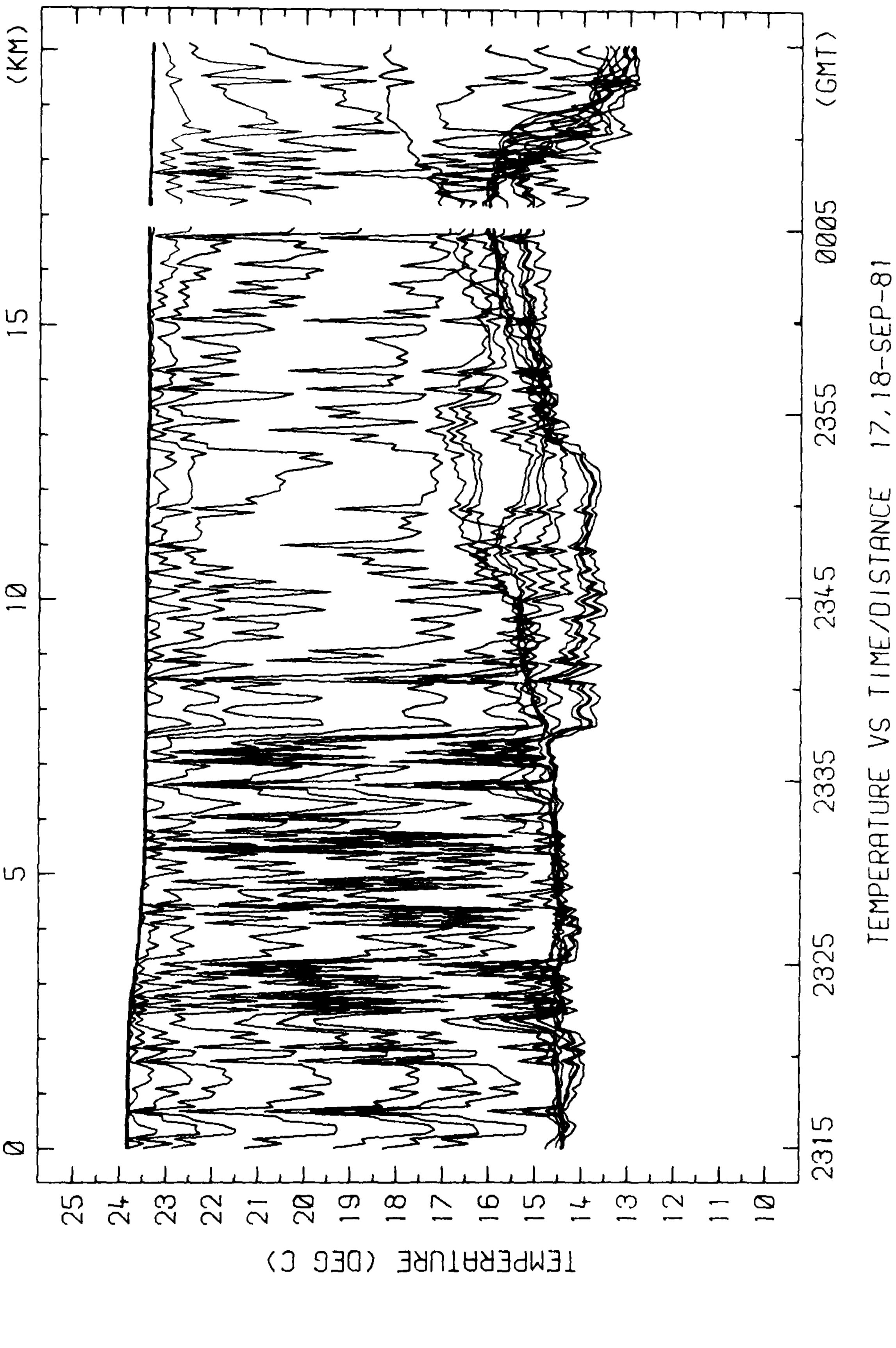

TEMPERATURE (DEG C)
28
27
26
25
24
23
22
21
20
19
0
5
10
(KM)
1130
1150
1210
1230
1250
1310
(GMT)
TEMPERATURE VS TIME/DISTANCE 14-SEP-81

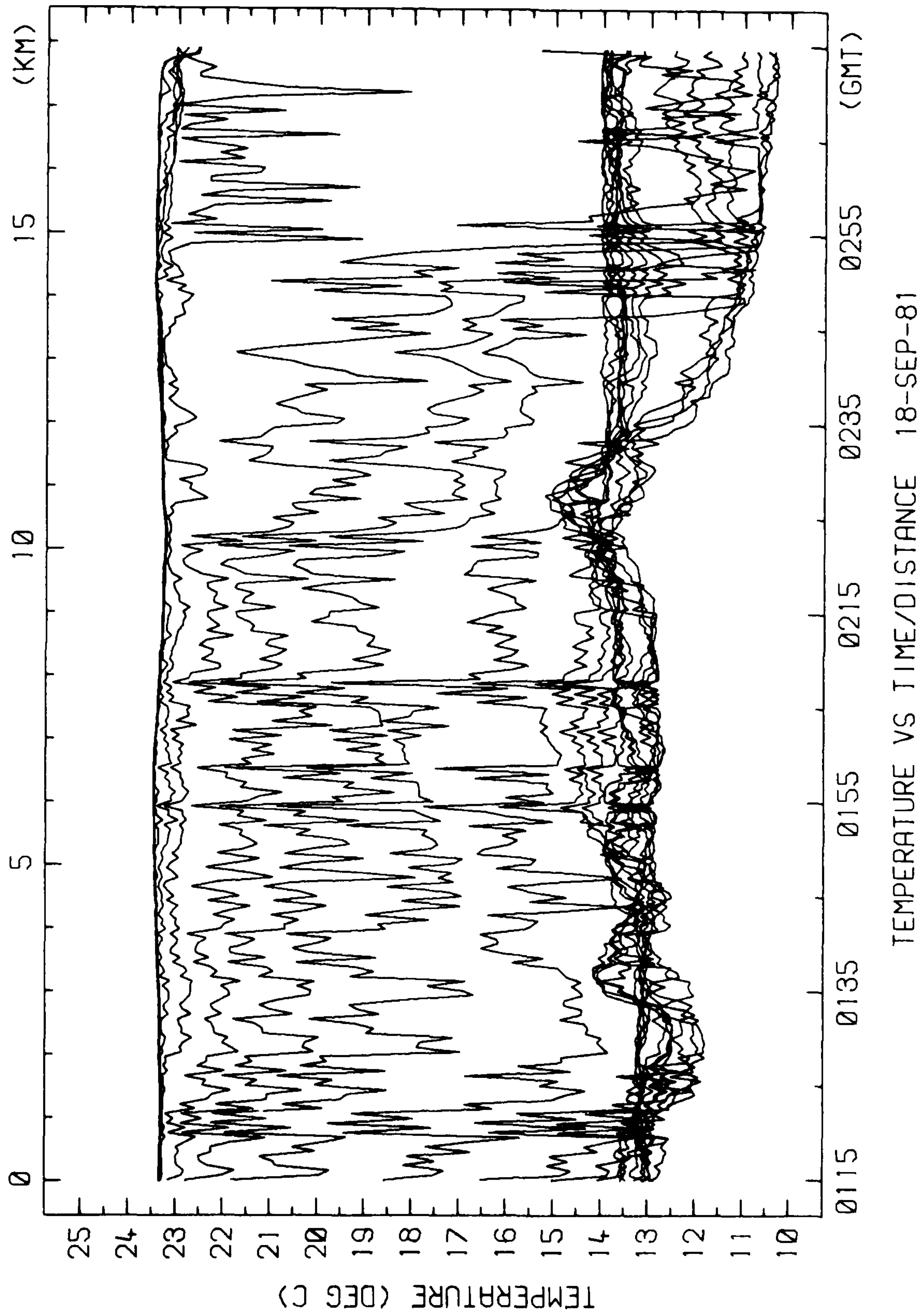


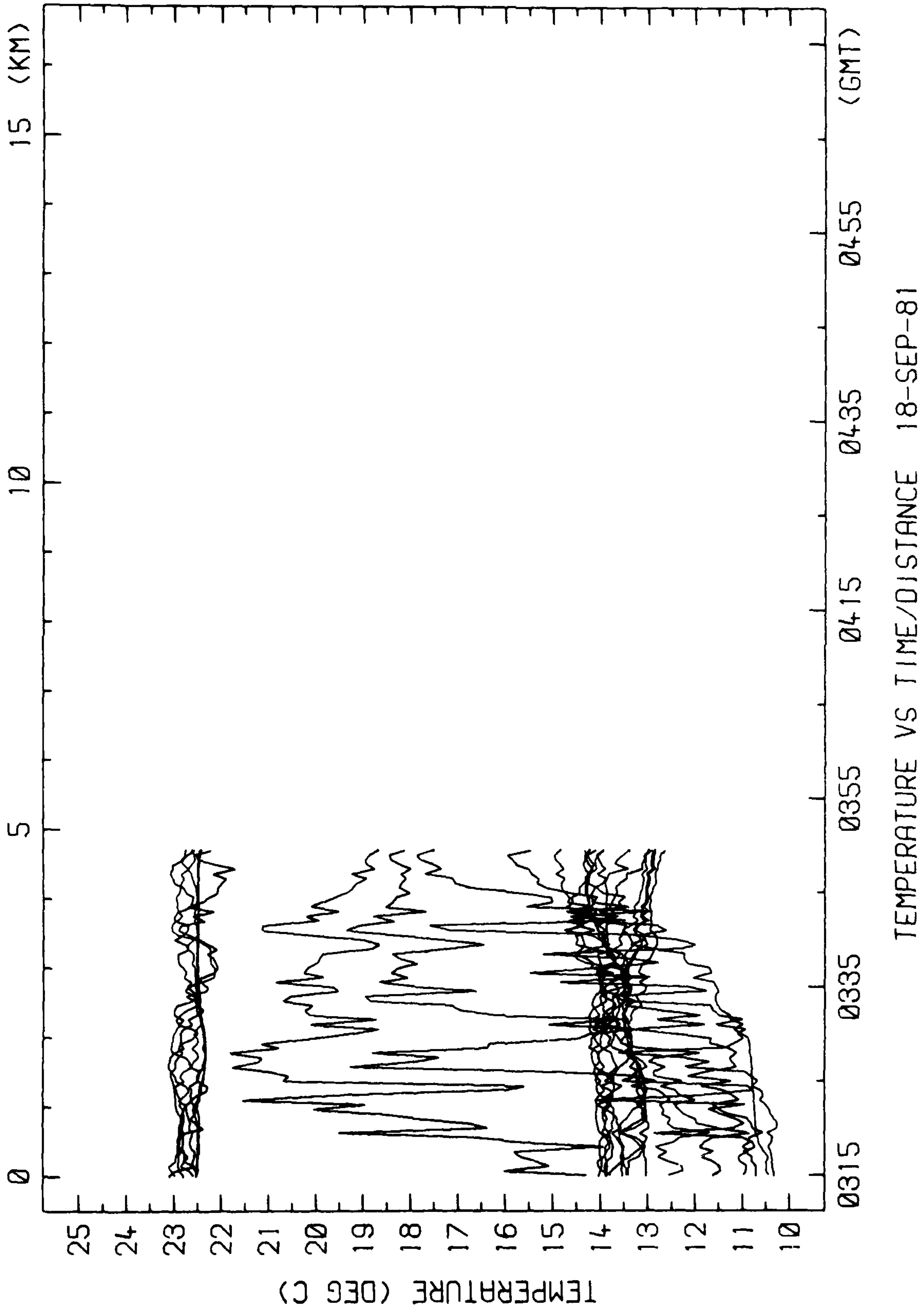
TEMPERATURE VS TIME/DISTANCE 17-SEP-81
TEMPERATURE (DEG C)
(KM)
0 5 10 15
(GMT)
1915 1935 1955 2015 2035 2055
25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10



TEMPERATURE VS TIME/DISTANCE 17-SEP-81


TEMPERATURE VS TIME/DISTANCE 17,18-SEP-81
TEMPERATURE (DEG C)
(KM)
(GMT)
0
5
10
15
2315
2325
2335
2345
2355
0005
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10


TEMPERATURE (DEG C)
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
0
5
10
15
(KM)
0115
0135
0155
0215
0235
0255
(GMT)
TEMPERATURE VS TIME/DISTANCE 18-SEP-81



TEMPERATURE (DEG C)
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
0
5
10
15 (KM)
0315
0335
0355
0415
0435
0455
(GMT)
TEMPERATURE VS TIME/DISTANCE 18-SEP-81

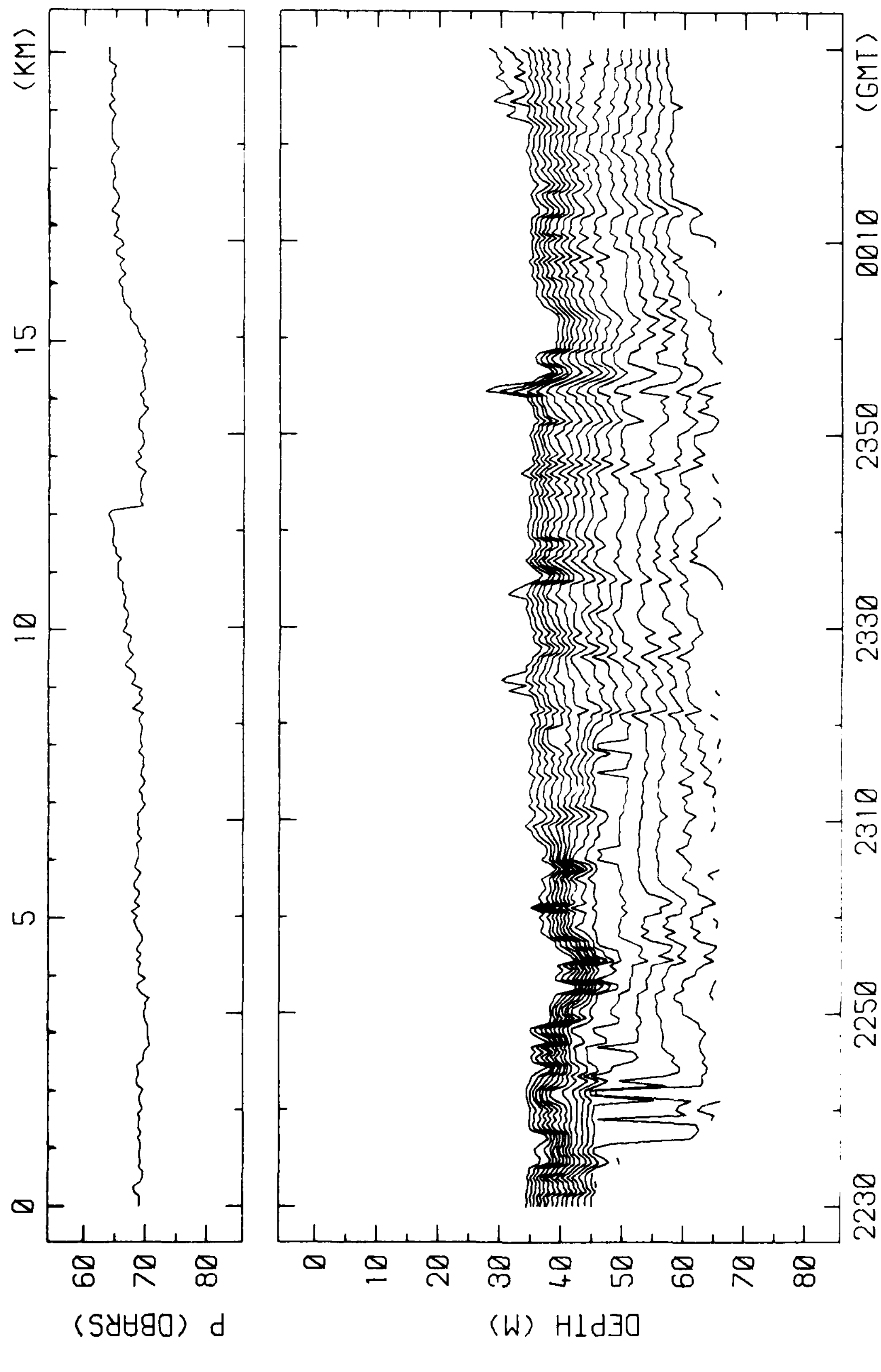
APPENDIX B

Isotherm Cross-Sections

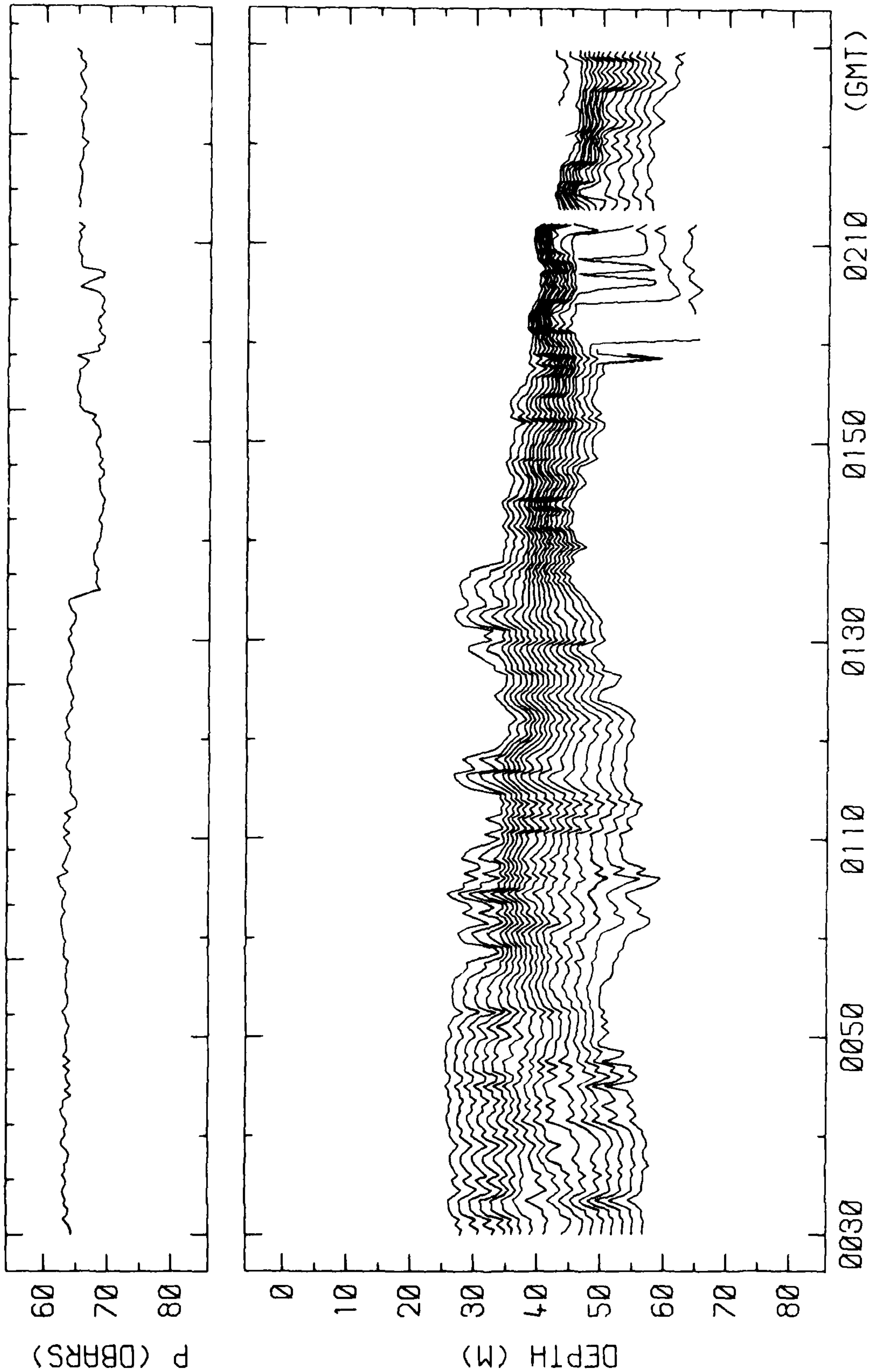
On the following pages there is a table followed by plots of the depths of isotherms at 0.5°C intervals. The depths of isotherms were obtained by linear interpolation between the low-pass filtered temperature observations shown in Appendix A. The values of the highest and lowest isotherms at the beginning of each two-hour plot are given in Table B1. The interpolation proceeded downward from the uppermost temperature measurement. The minimum depths of each isotherm are plotted, thereby avoiding ambiguities caused by temperature inversions. There are errors in isotherm depths associated with kiting of the chain. The depth record from one of the pressure sensors is plotted to show the magnitude of these errors. The pressure sensors occasionally malfunctioned. For example, the change in depth at 2340 on 10 September is erroneous.

Table B1. Value of the highest and lowest isotherm at the beginning of each two-hour plot of isotherm depth.

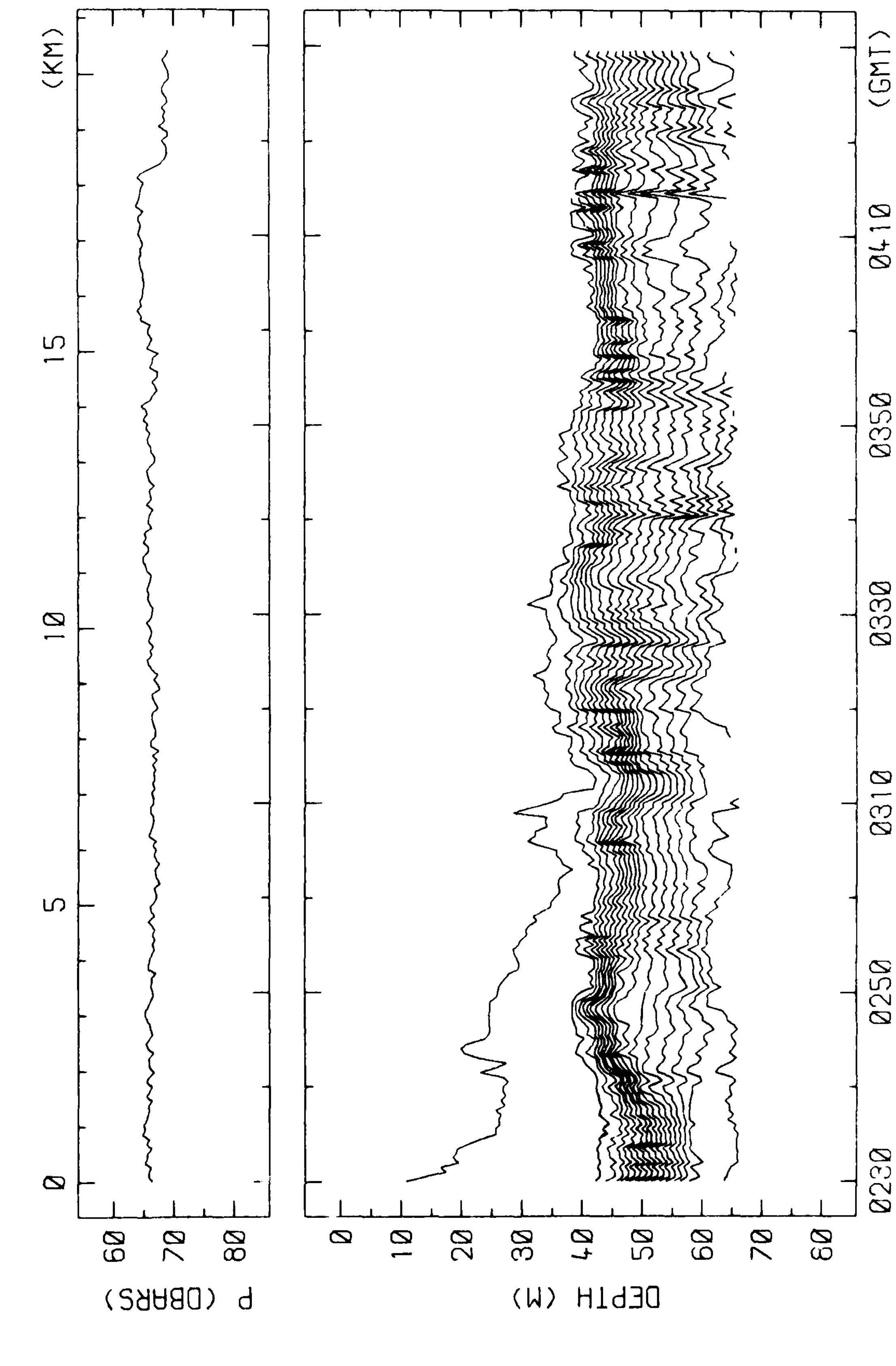
Run	Date (Sept)	Time (GMT)	Isotherm Highest	Lowest (°C)
1	10	2230	20.5	13.5
	11	0030	20.5	13.0
		0230	23.0	15.0
		0430	23.0	15.5
		0630	24.0	18.0
		0830	23.0	18.0
		1030	22.5	16.5
		1230	23.0	16.5
		1430	21.5	15.0
		1630	23.5	15.0
		1830	23.5	15.5
		2030	23.5	14.5
		2230	23.5	14.0
	12	0030	23.5	15.5
		0230	26.5	23.0
		0430	27.5	24.5
		0630	26.5	26.0
		0852	27.0	26.5
		1052	26.0	26.0
2	14	0130	27.0	21.0
		0330	27.0	20.5
		0530	27.0	21.0
		0730	27.0	20.0
		0930	26.5	20.0
		1130	26.0	20.0
3	17	1915	23.5	15.0
		2115	23.5	16.0
		2315	23.5	14.5
	18	0115	23.0	13.0
		0315	22.0	13.0



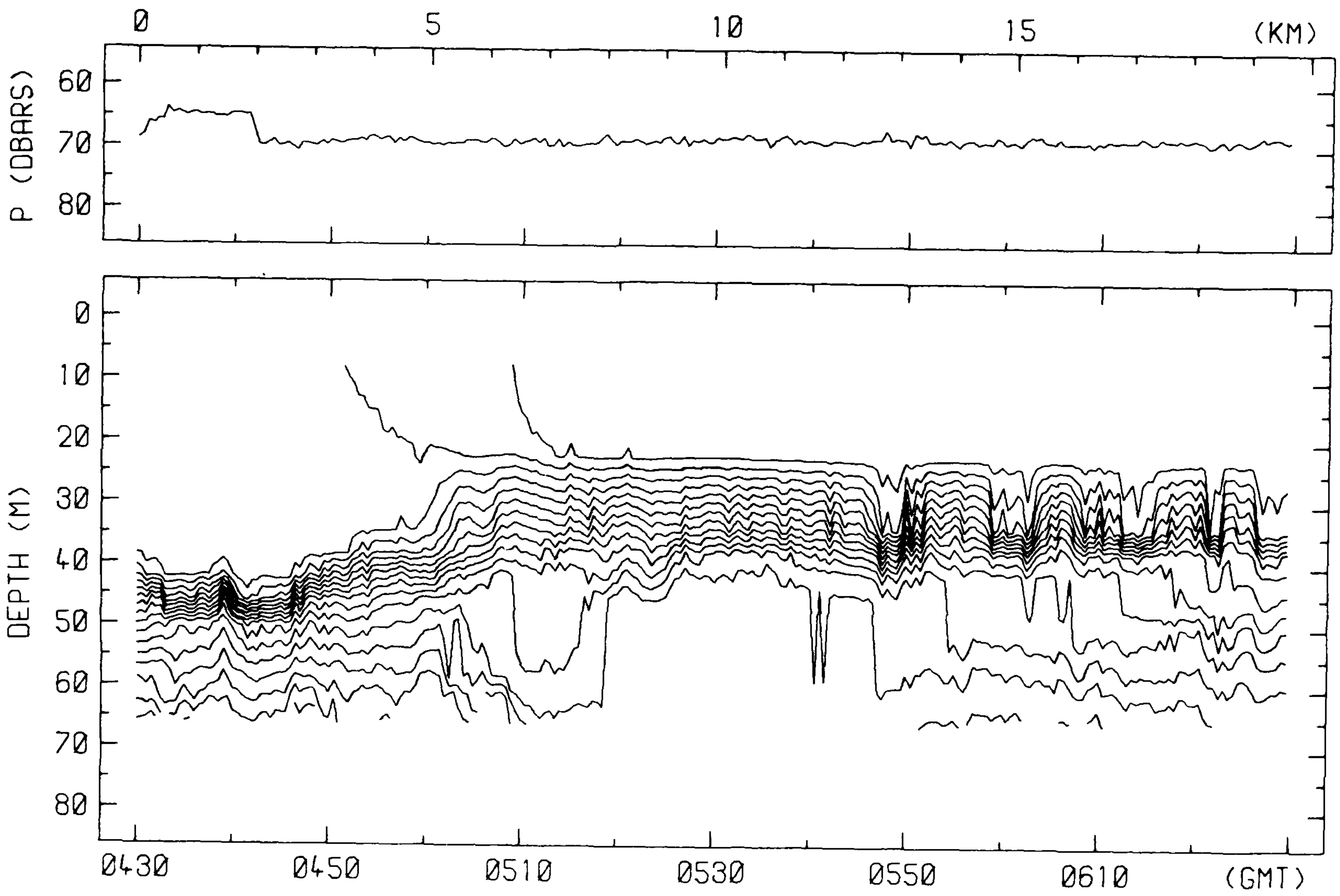
PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 10,11-SEP-81



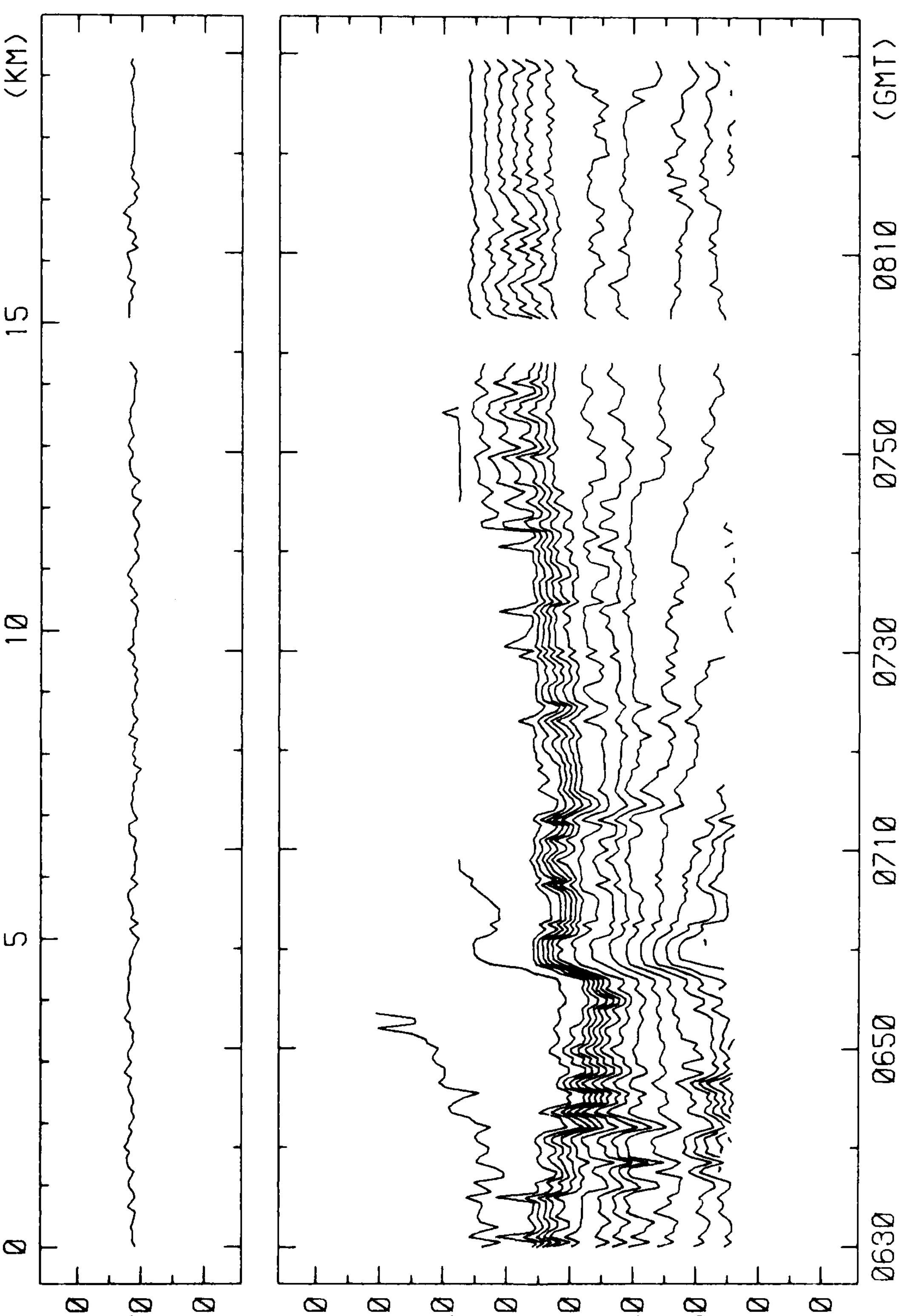
PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 11-SEP-81



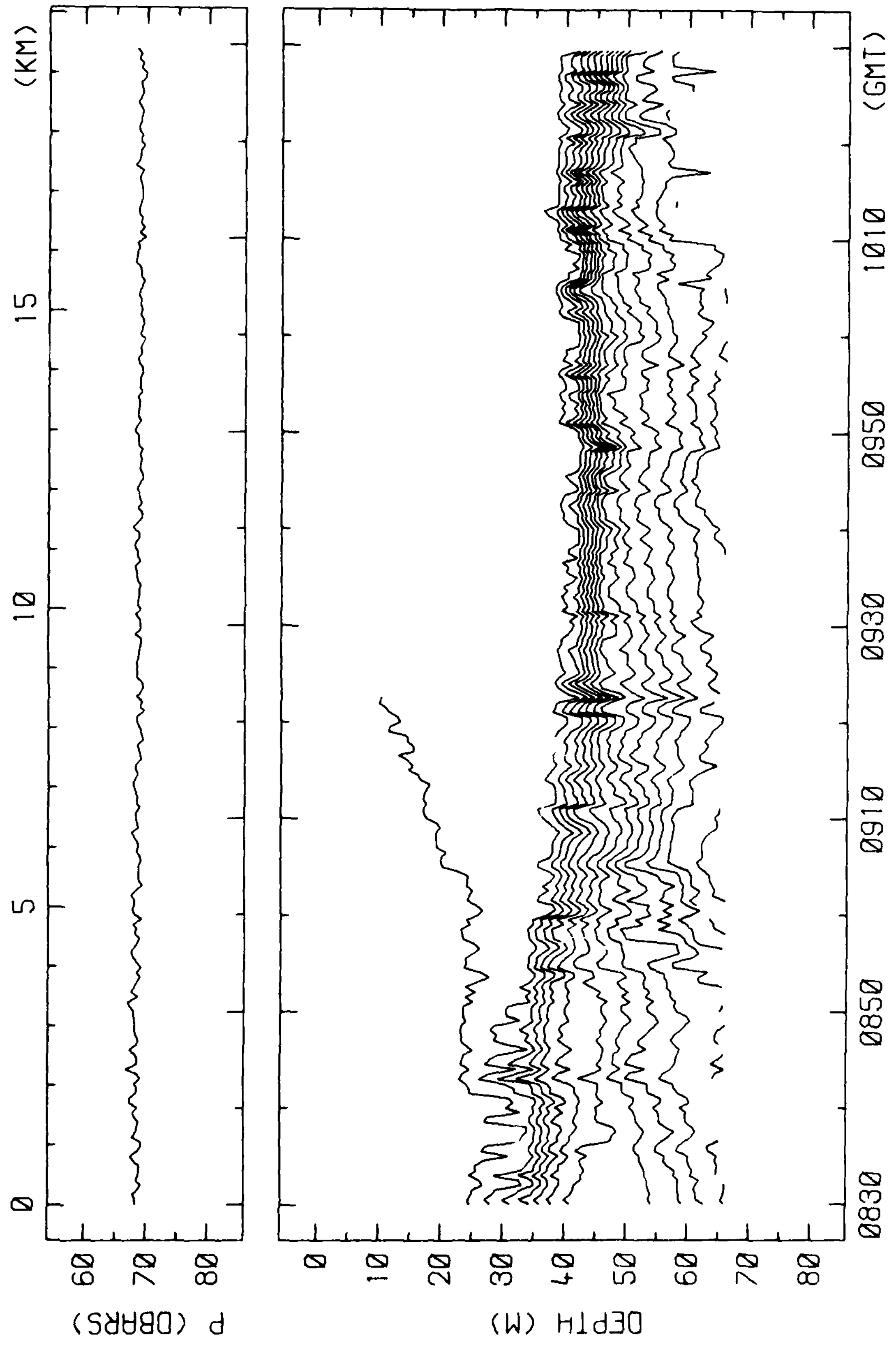
PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 11-SEP-81



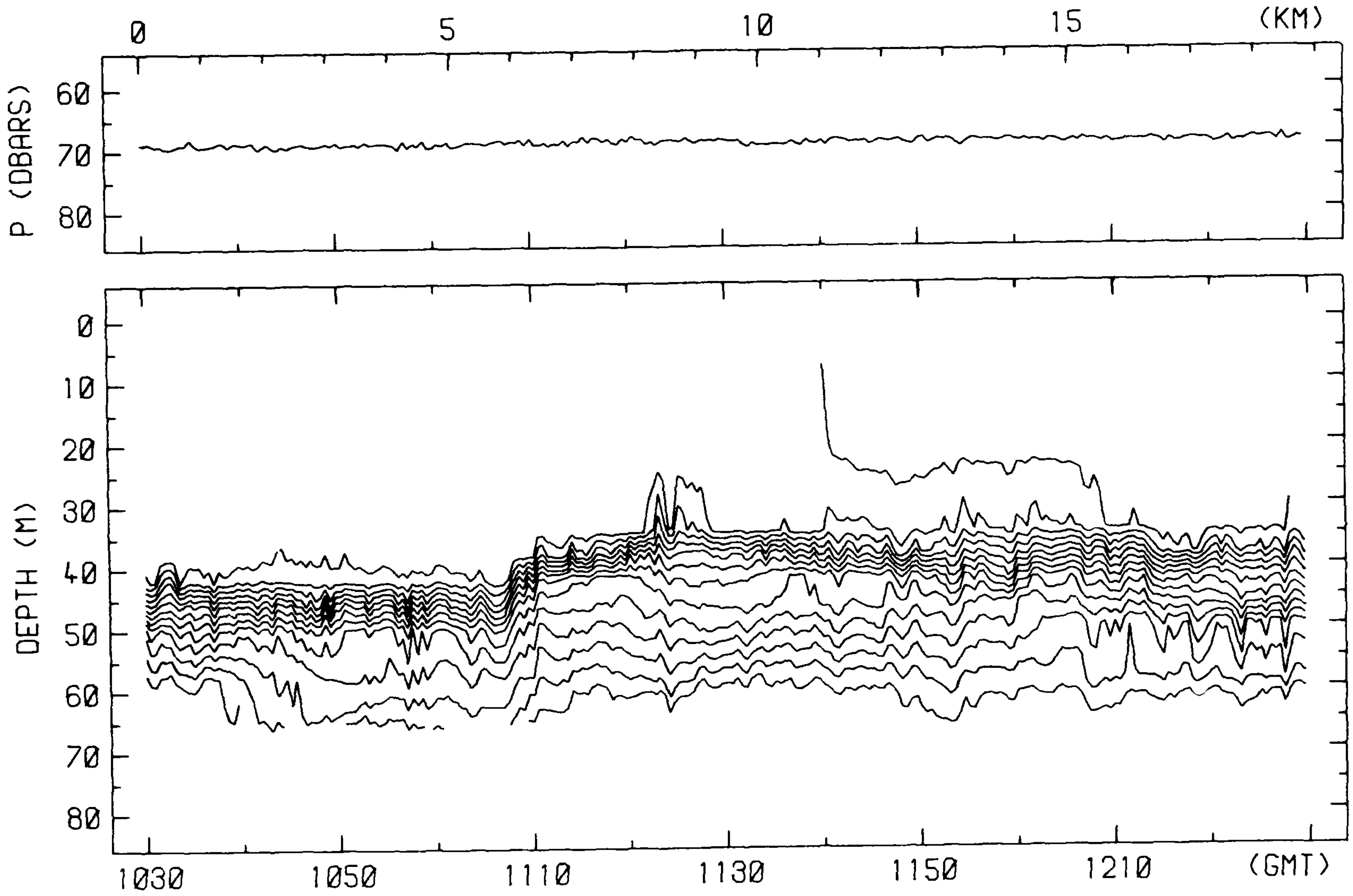
PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 11-SEP-81



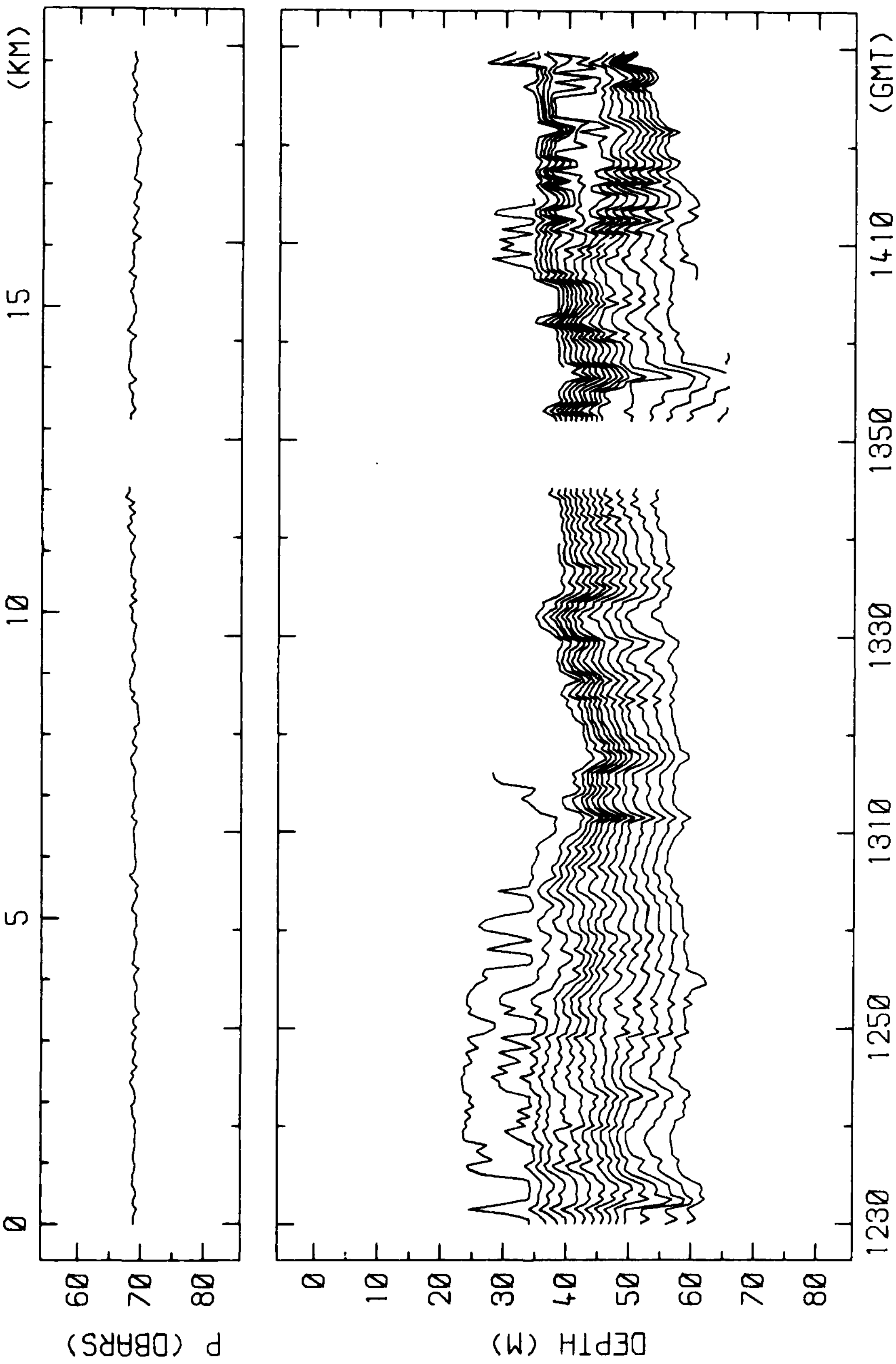
PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 11-SEP-81



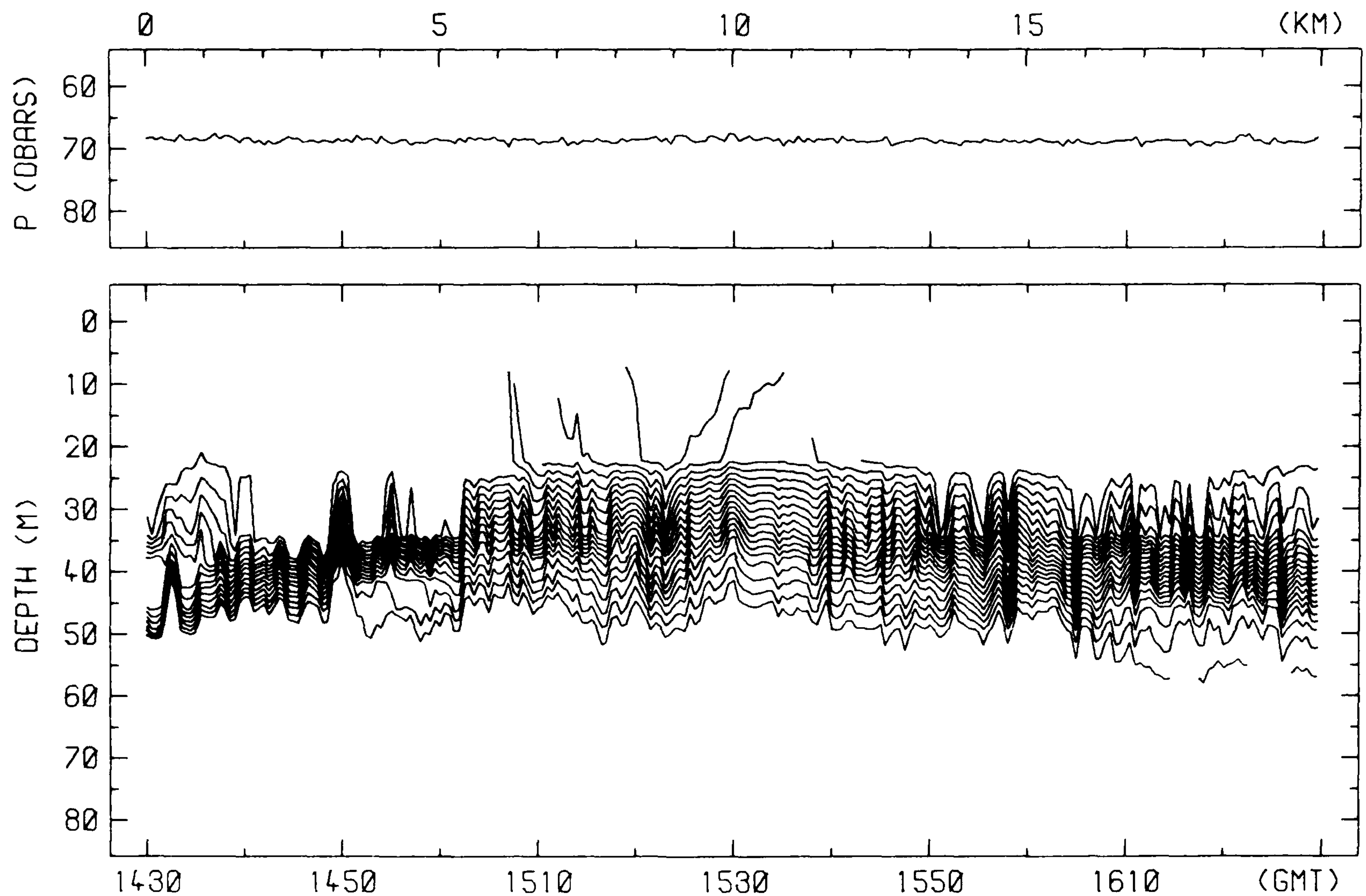
PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 11-SEP-81



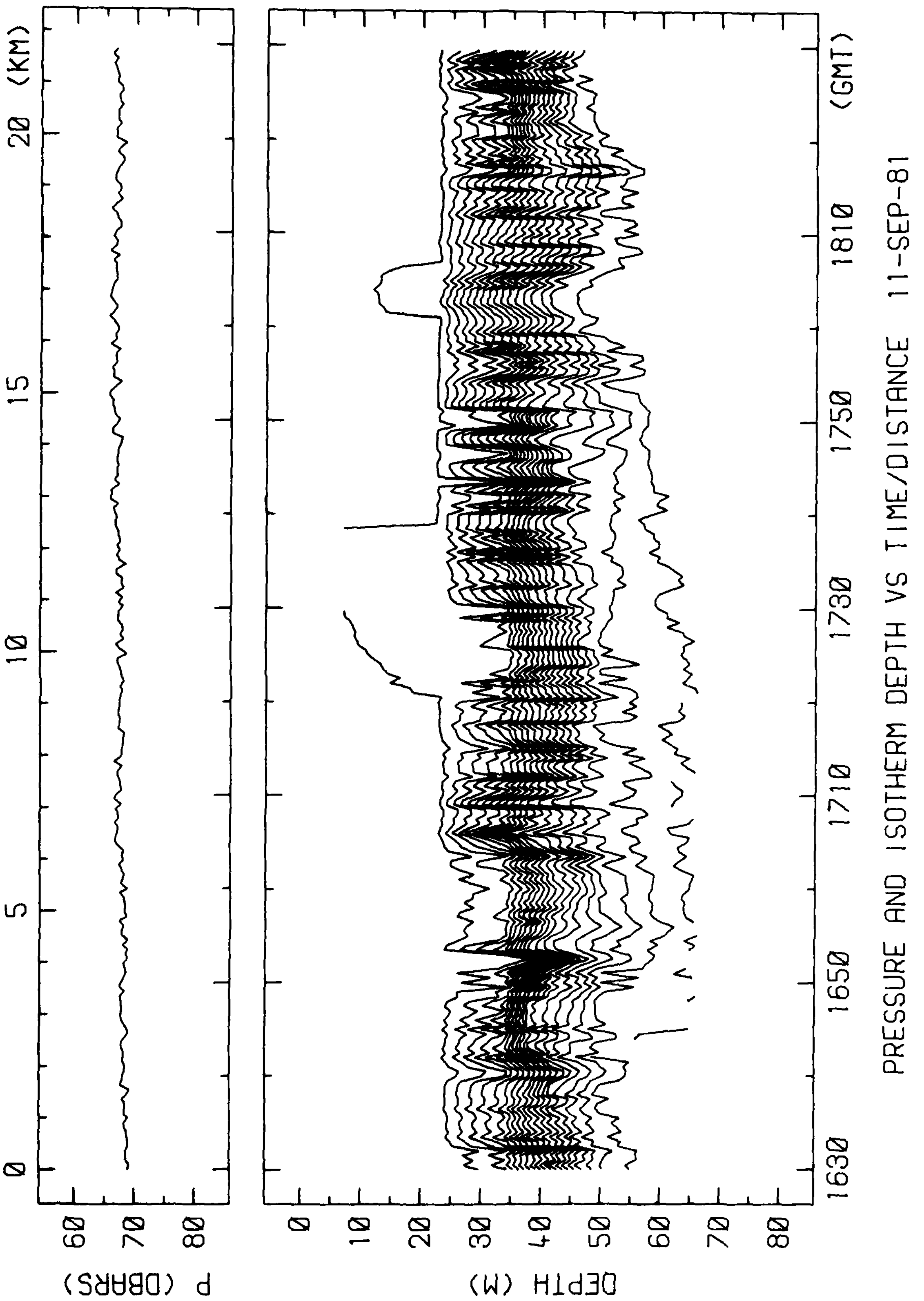
PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 11-SEP-81



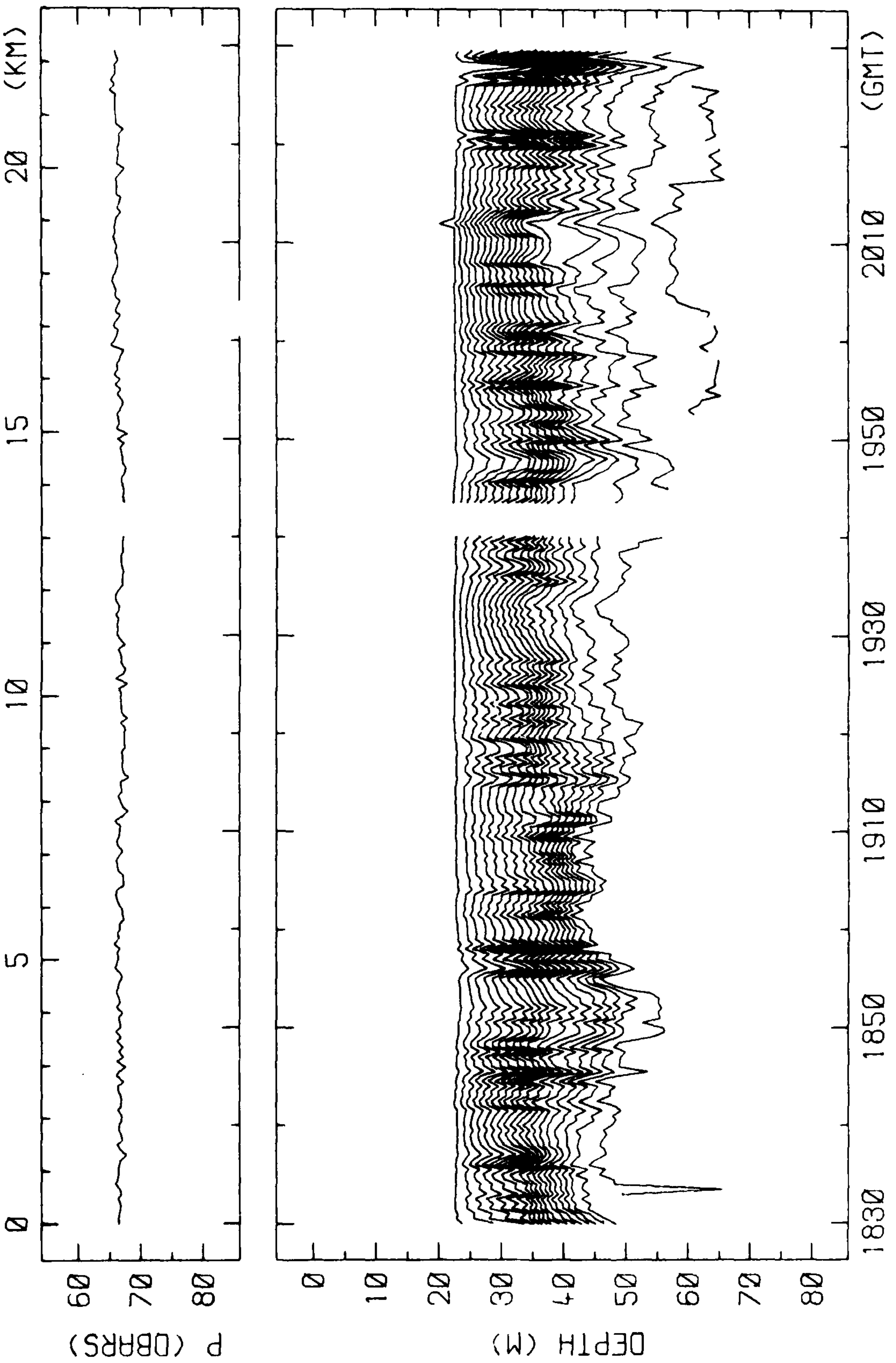
PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 11-SEP-81



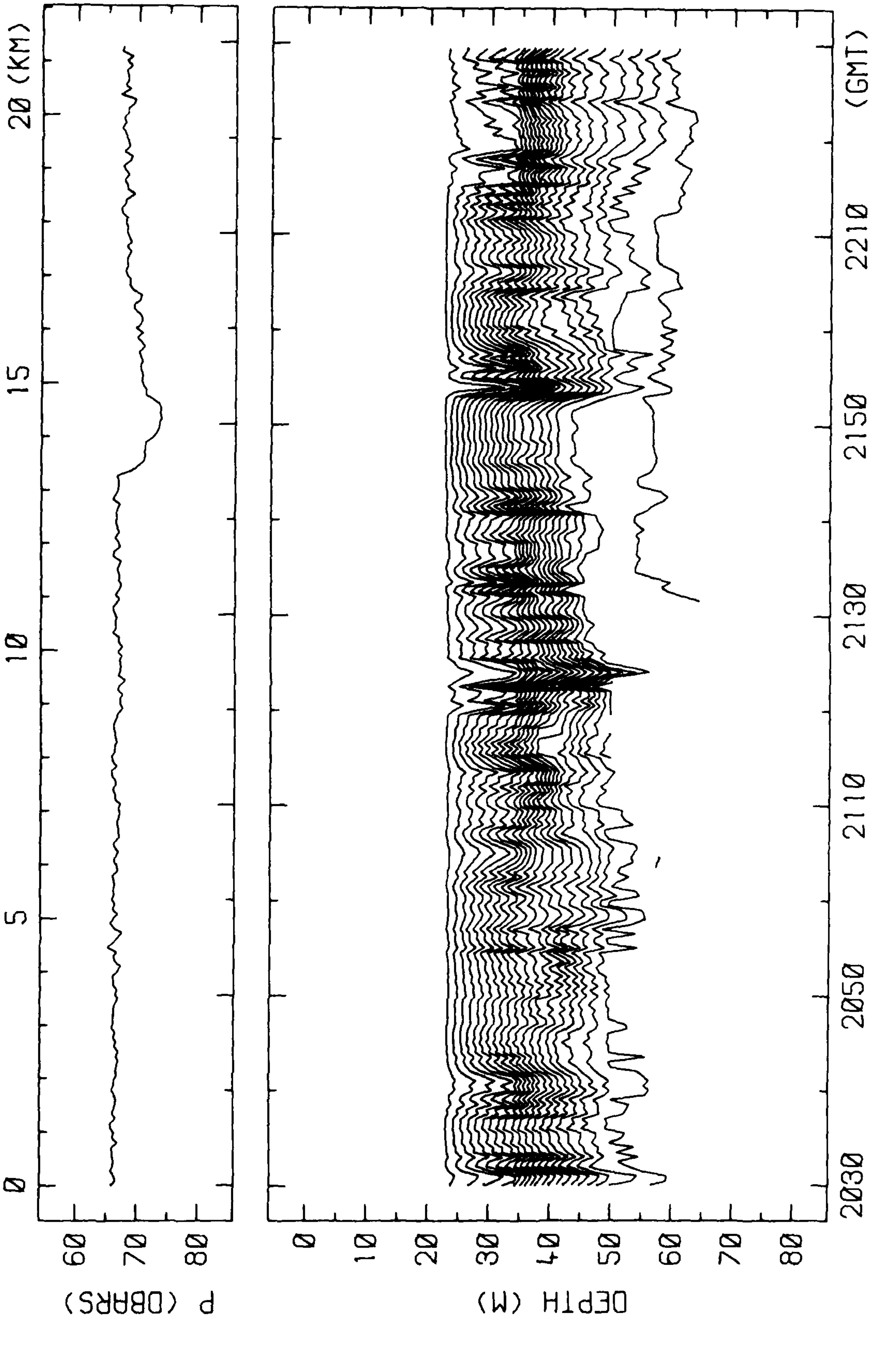
PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 11-SEP-81



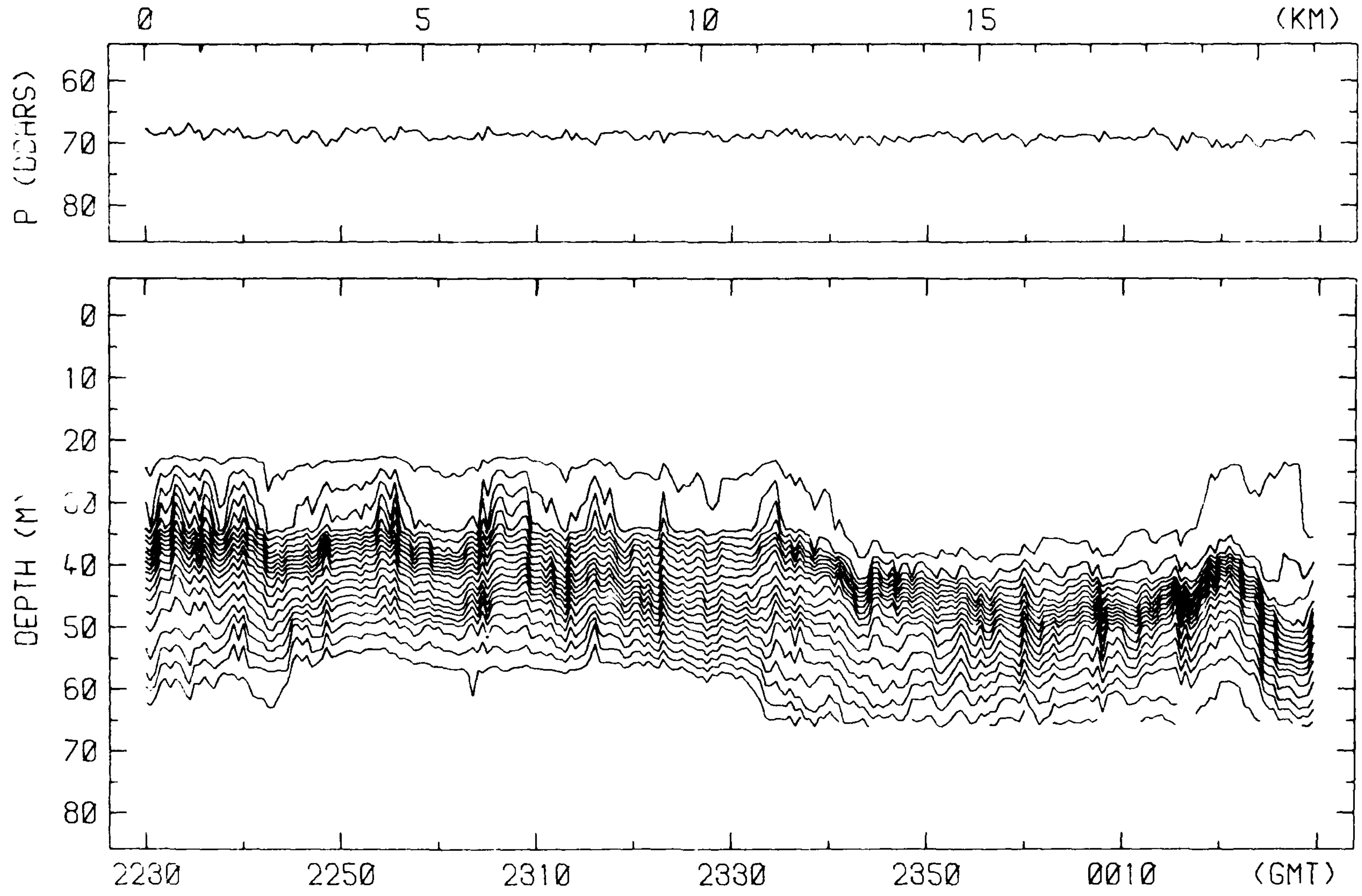
PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 11-SEP-81



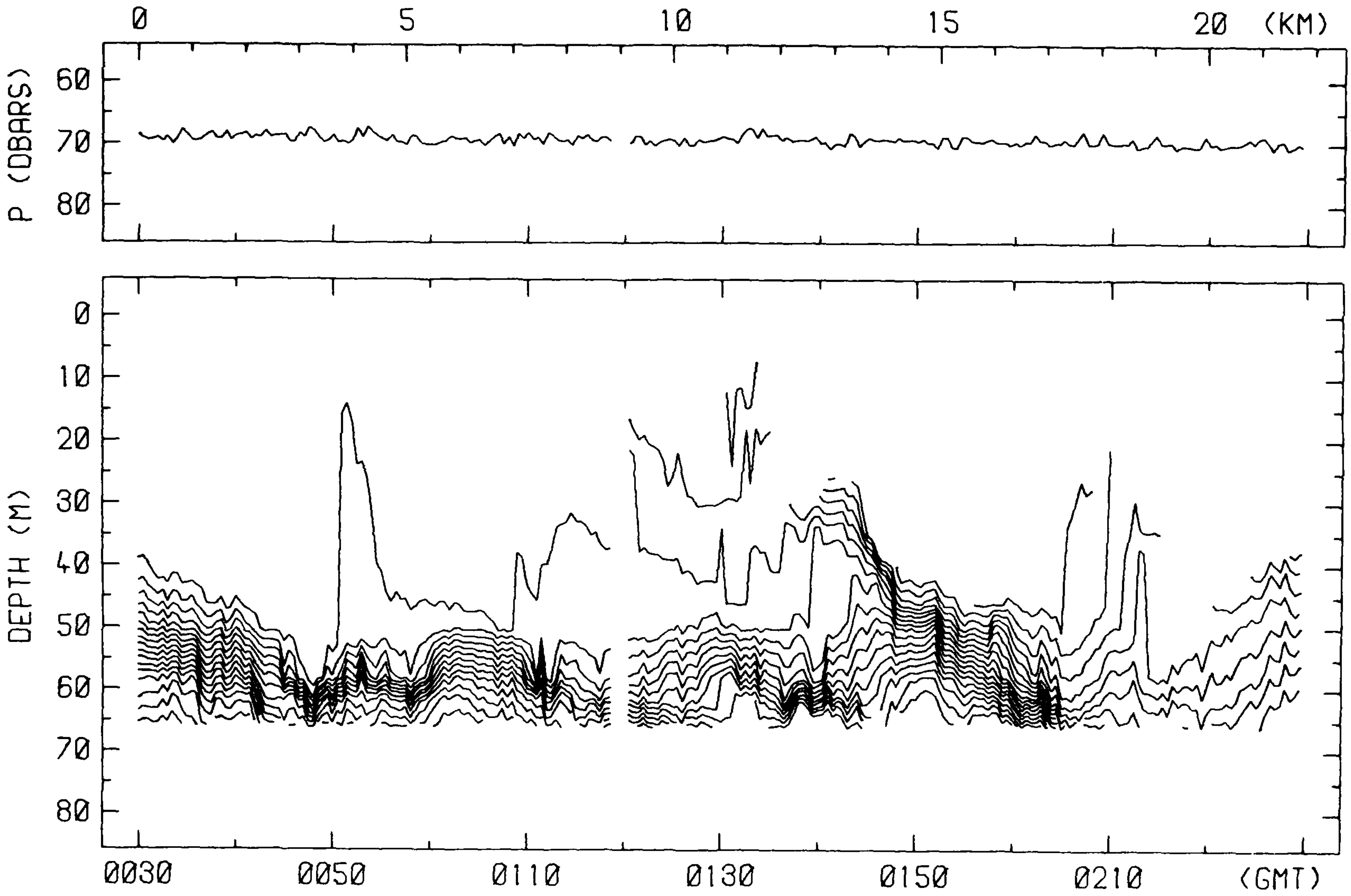
PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 11-SEP-81



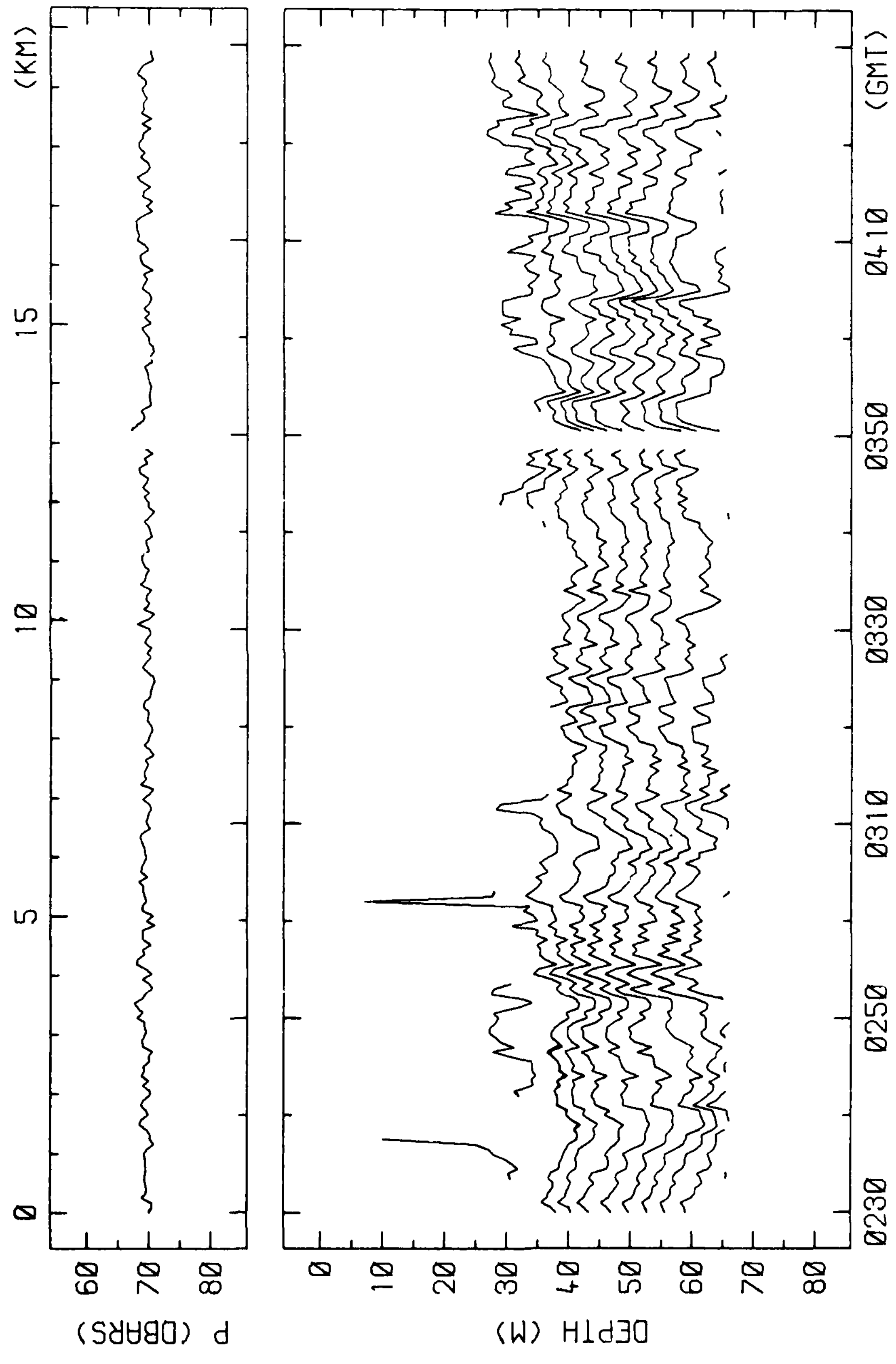
PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 11-SEP-81



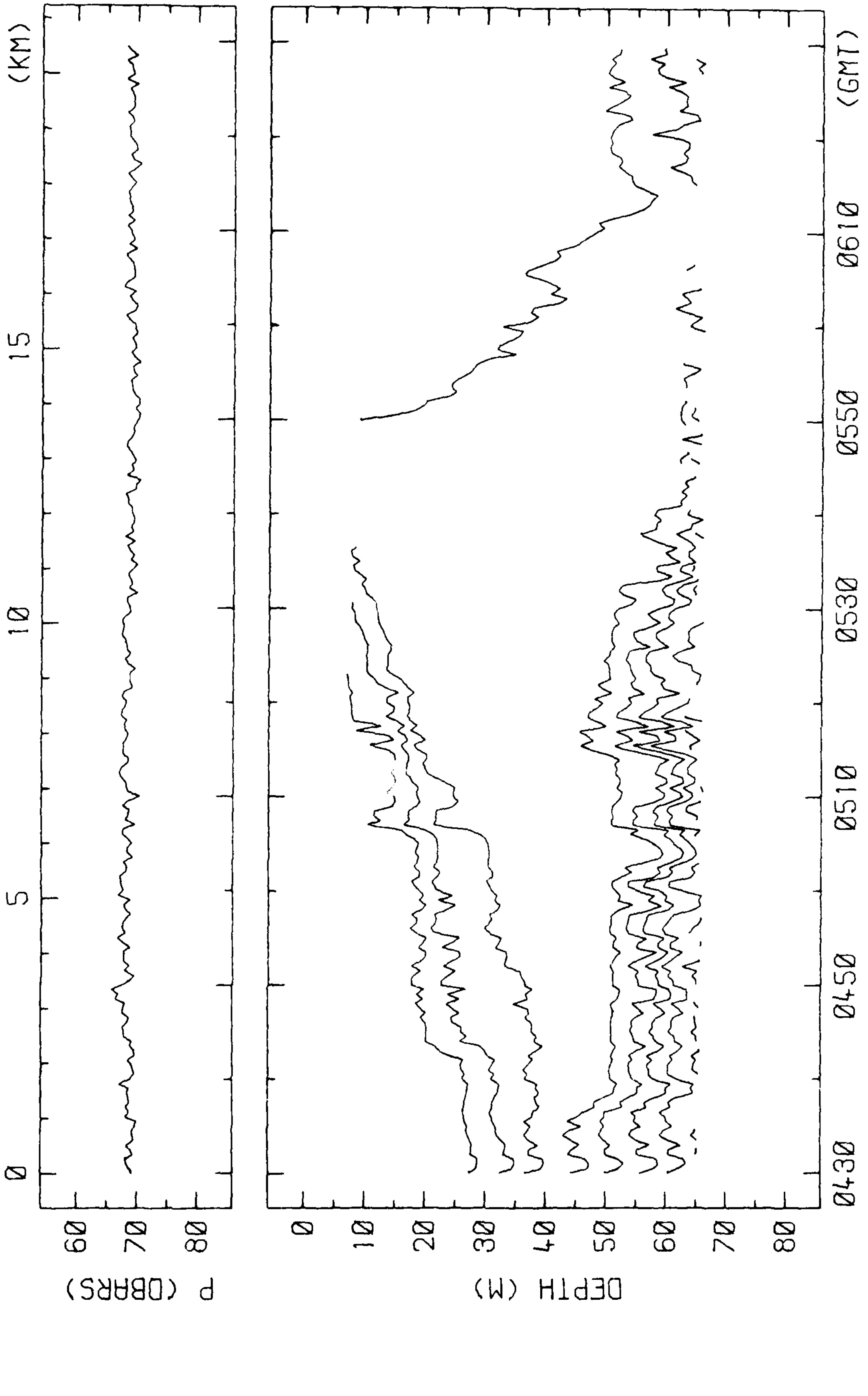
PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 11,12-SEP-81



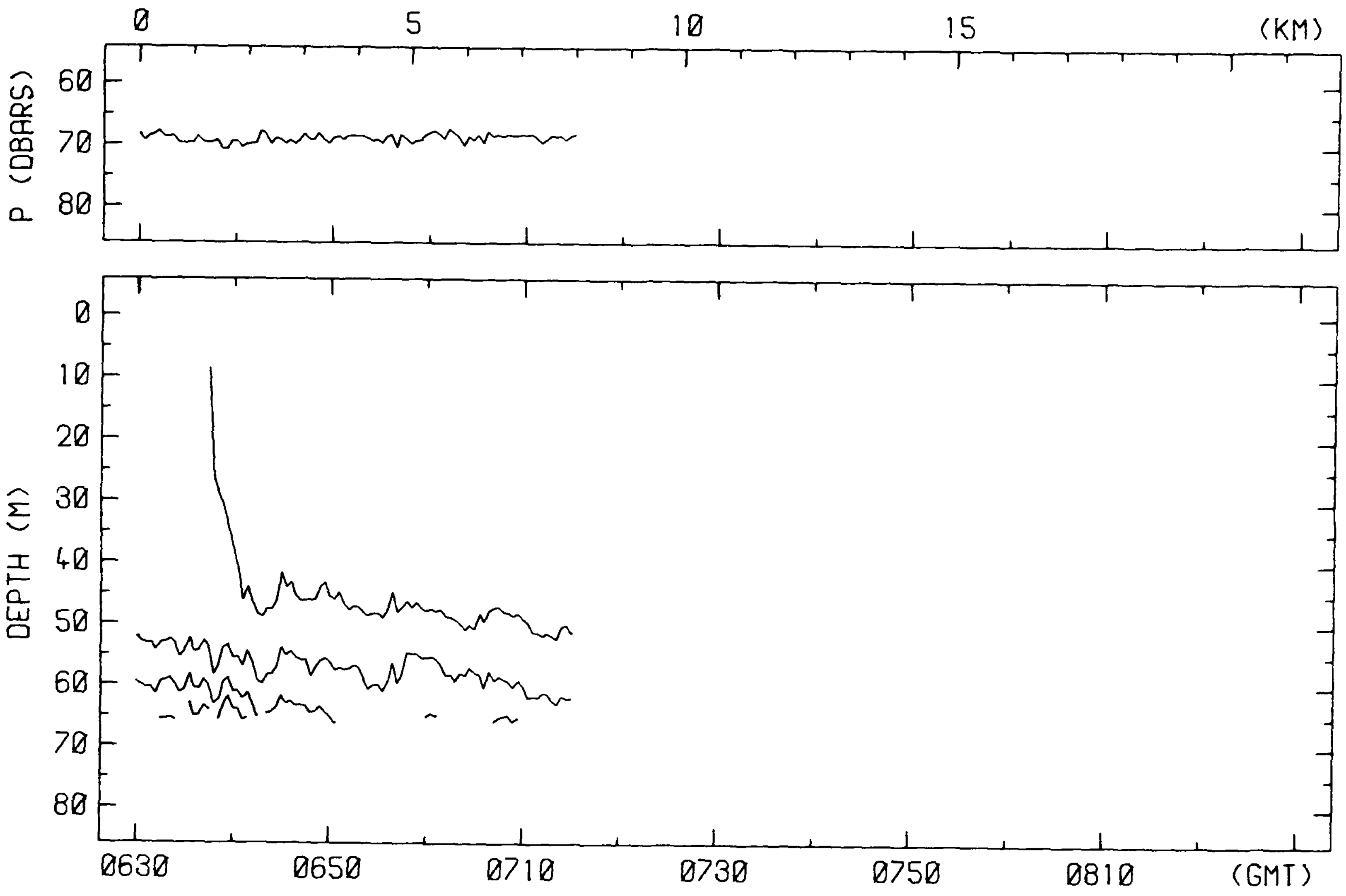
PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 12-SEP-81



PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 12-SEP-81



PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 12-SEP-81



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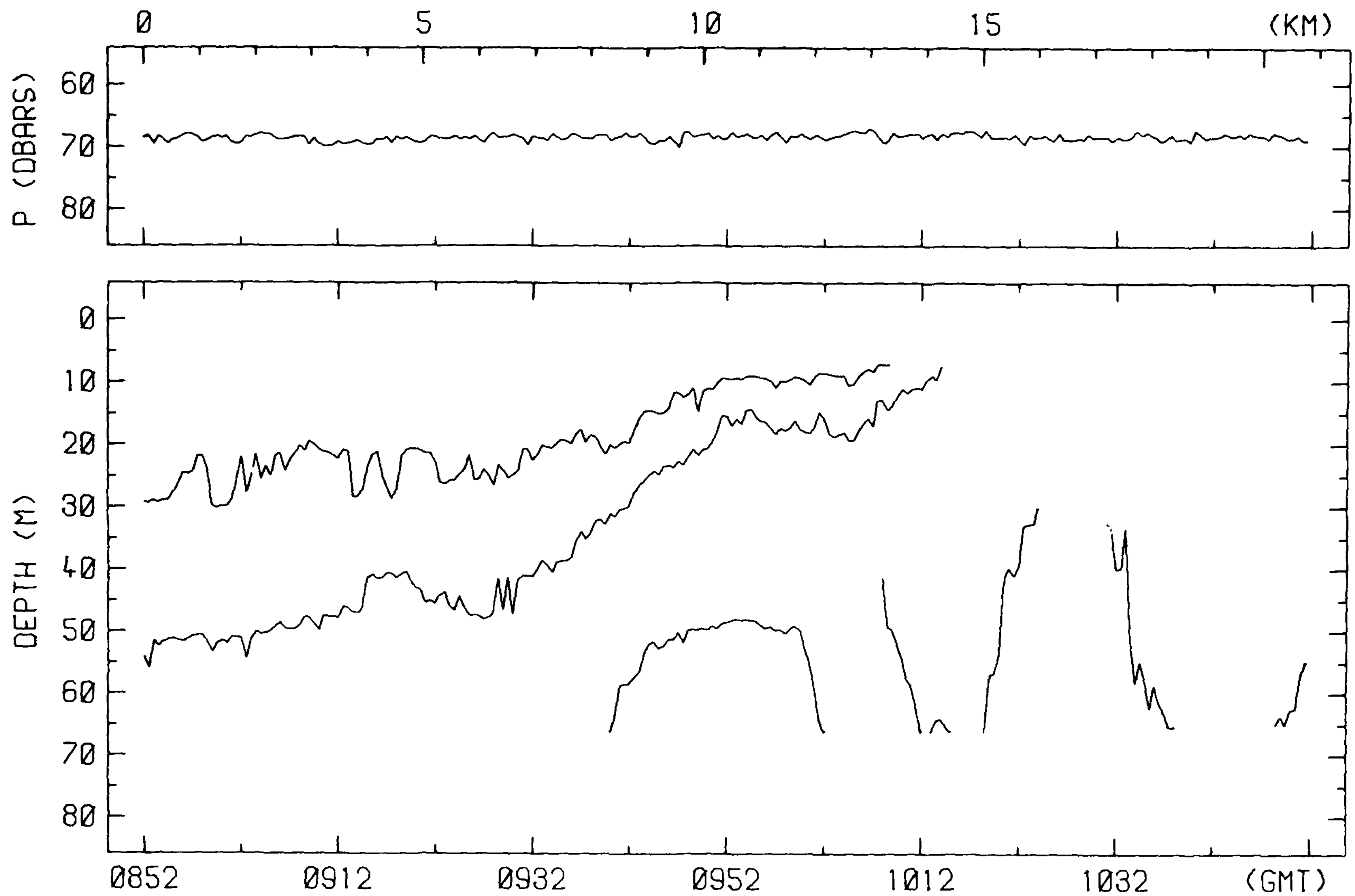
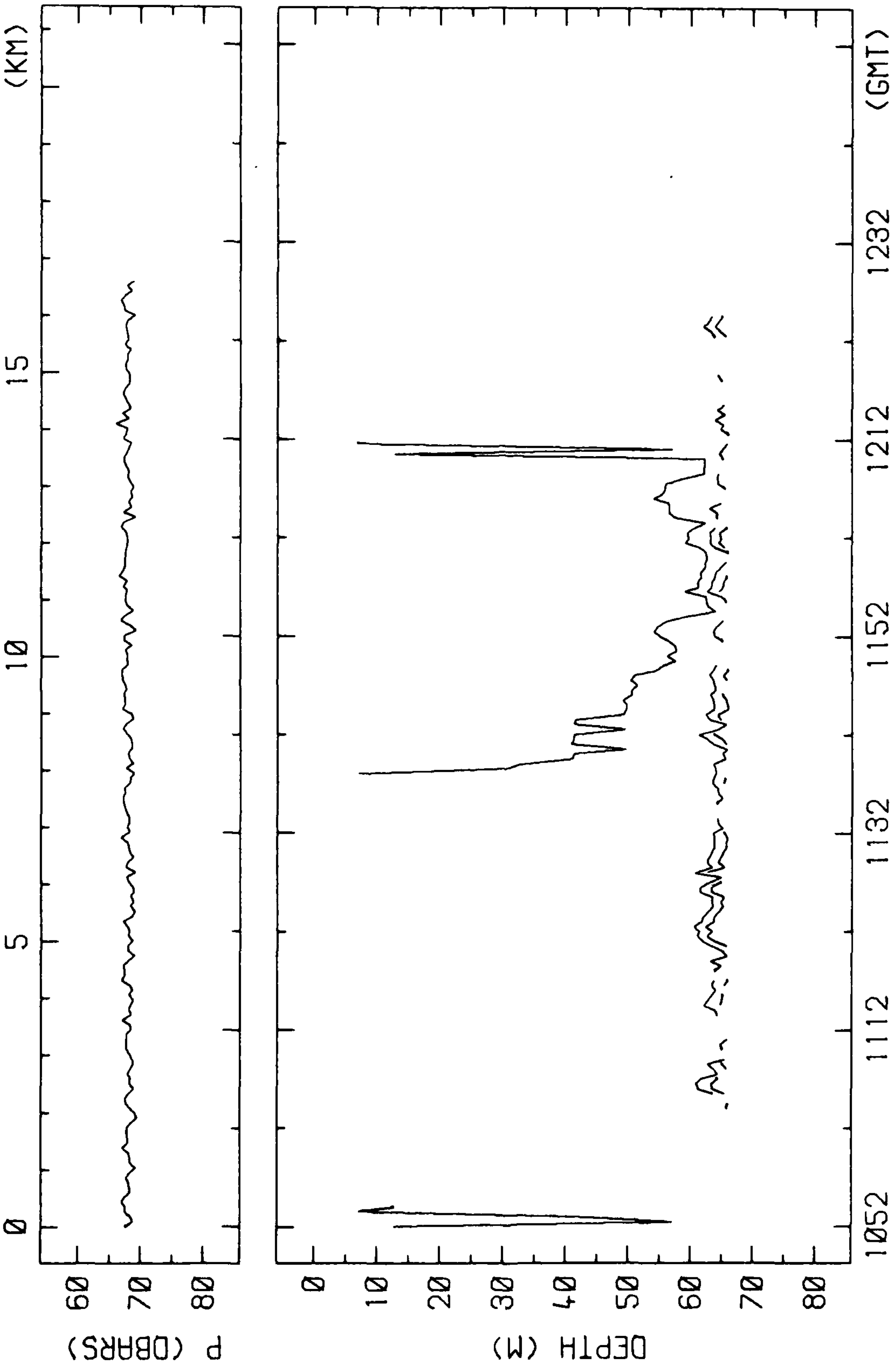


PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 12-SEP-81



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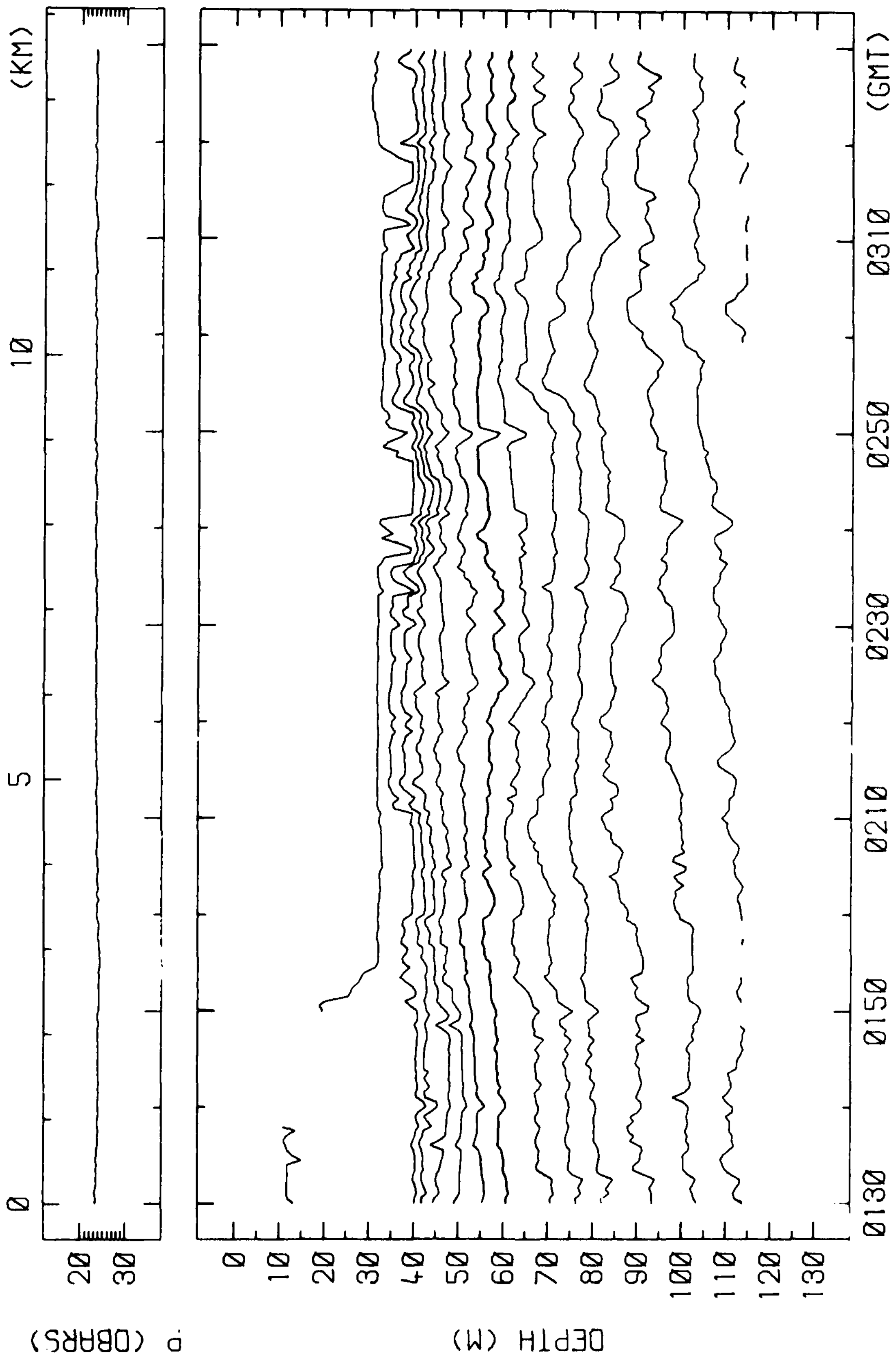
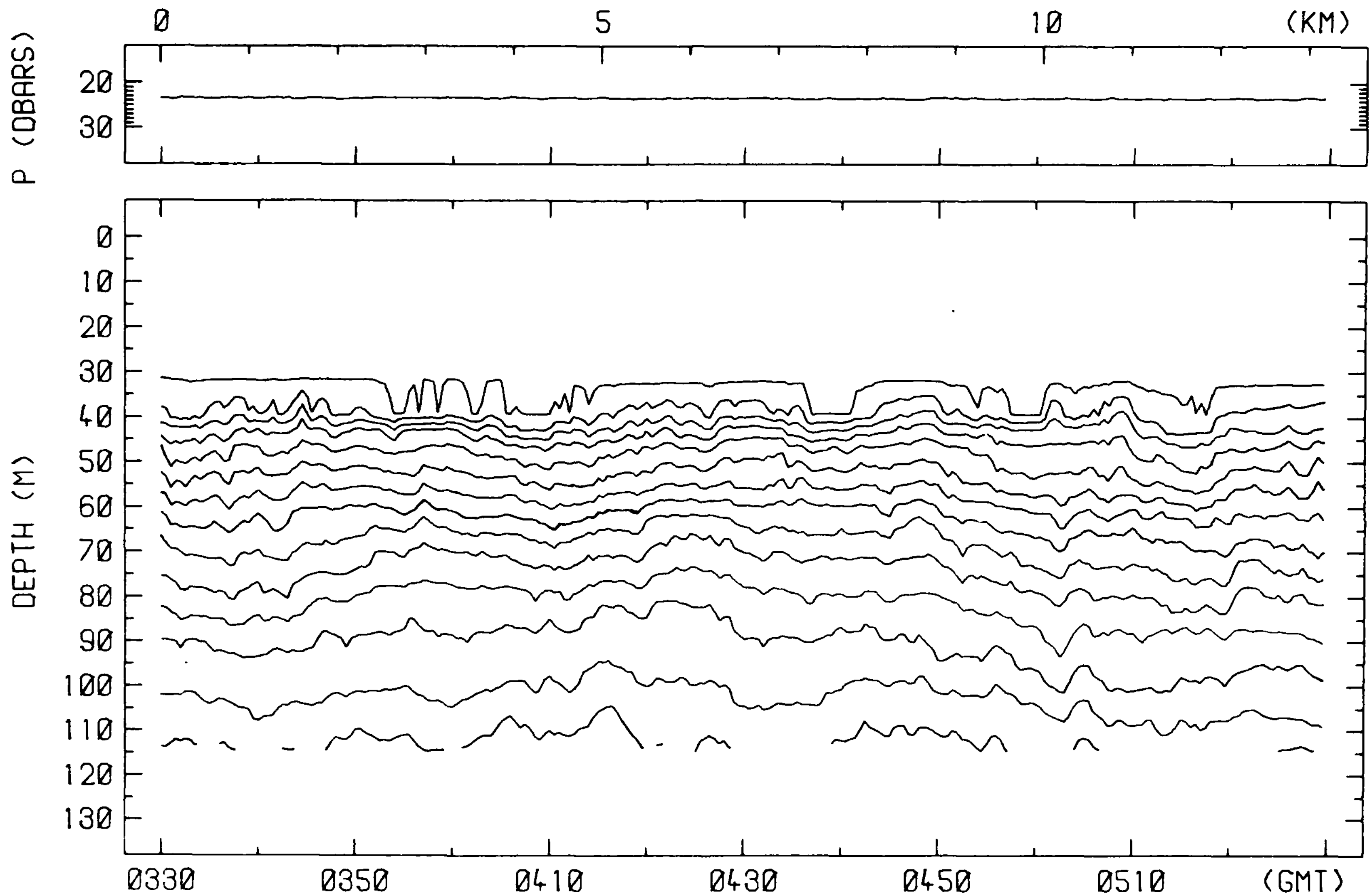
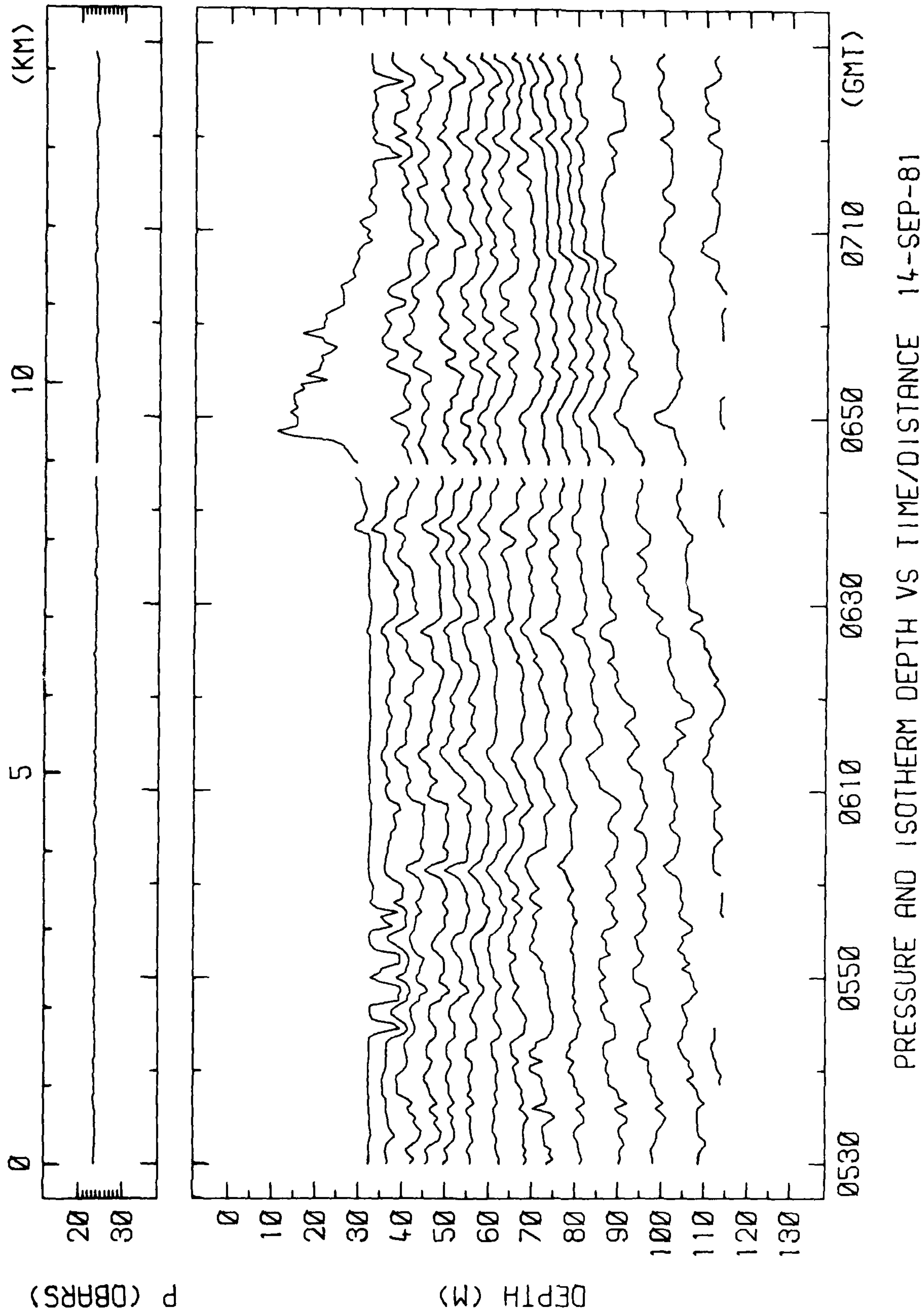


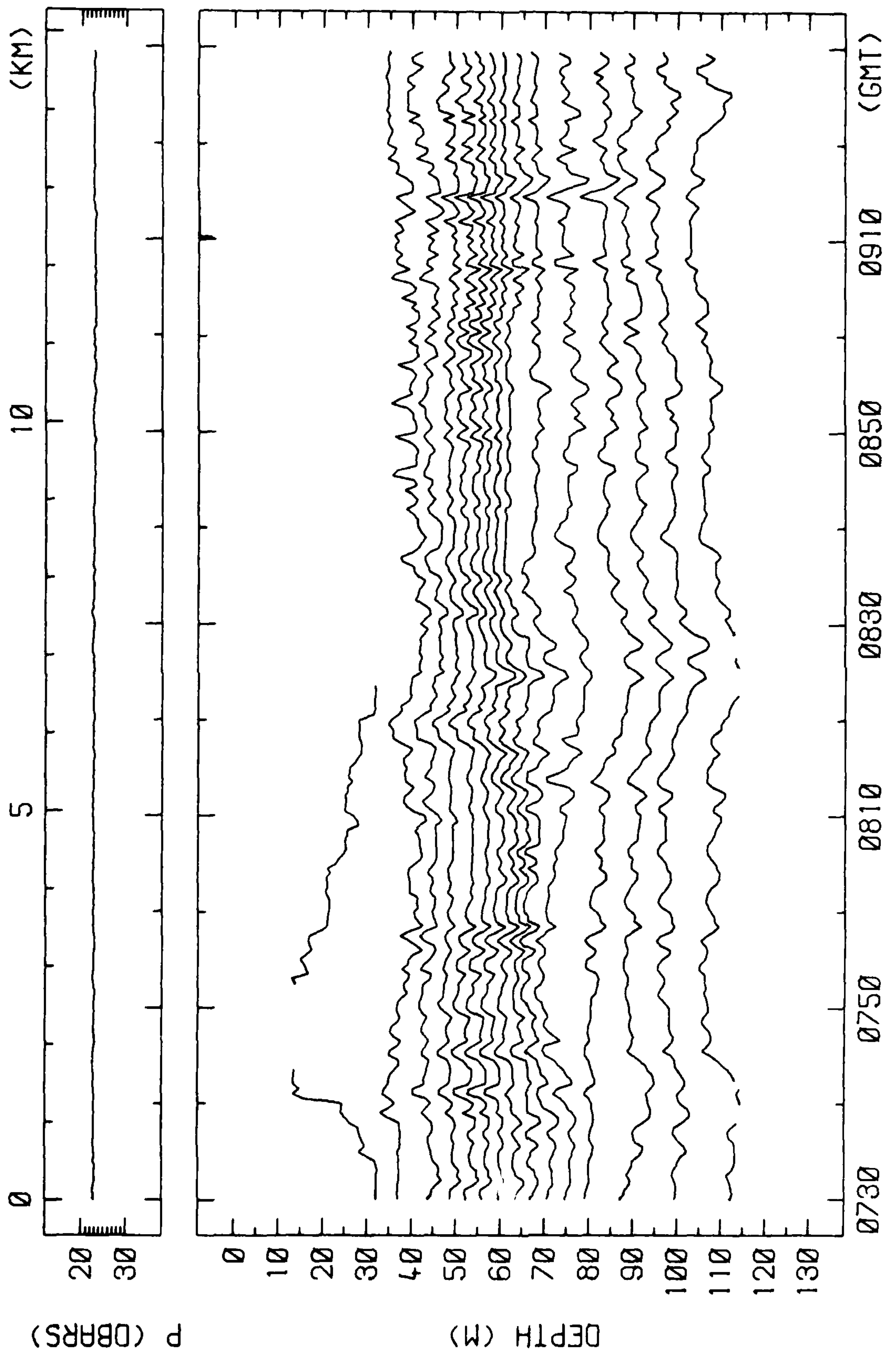
PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 14-SEP-81



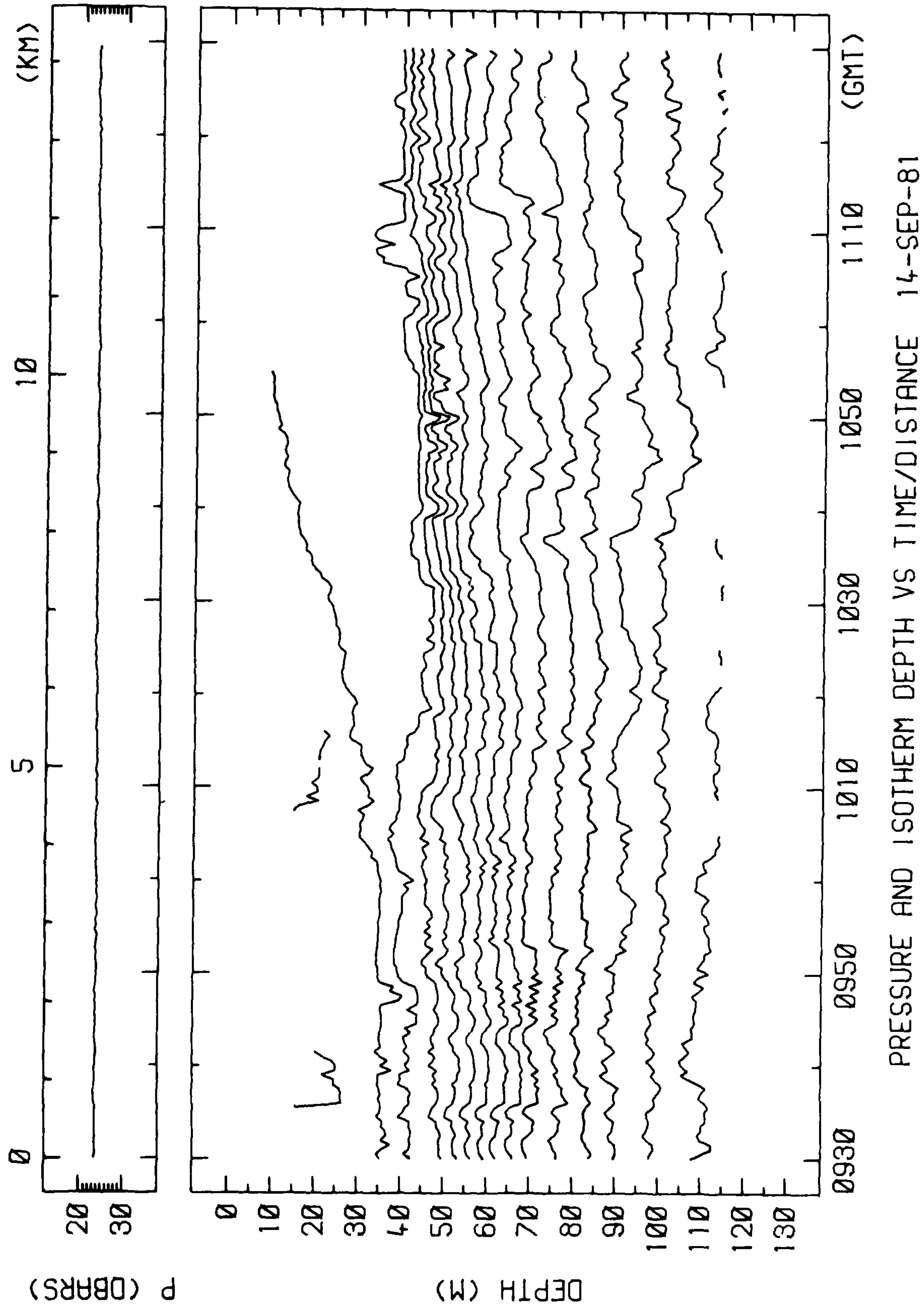
PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 14-SEP-81

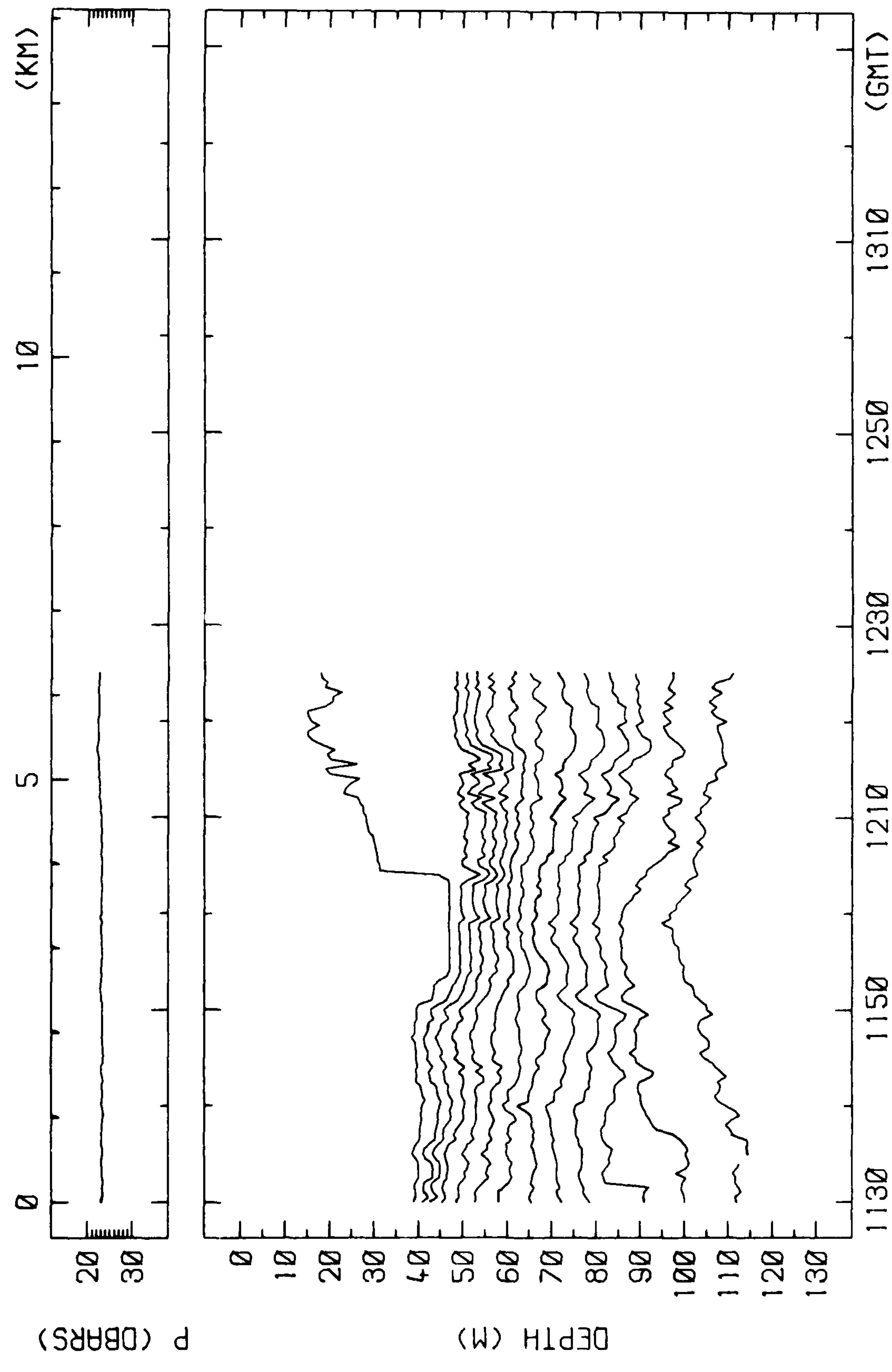


PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 14-SEP-81
(GMT)
0530
0550
0610
0630
0650
0710
(KM)
0
5
10
P (DBARS)
20
30
DEPTH (M)
0
10
20
30
40
50
60
70
80
90
100
110
120
130

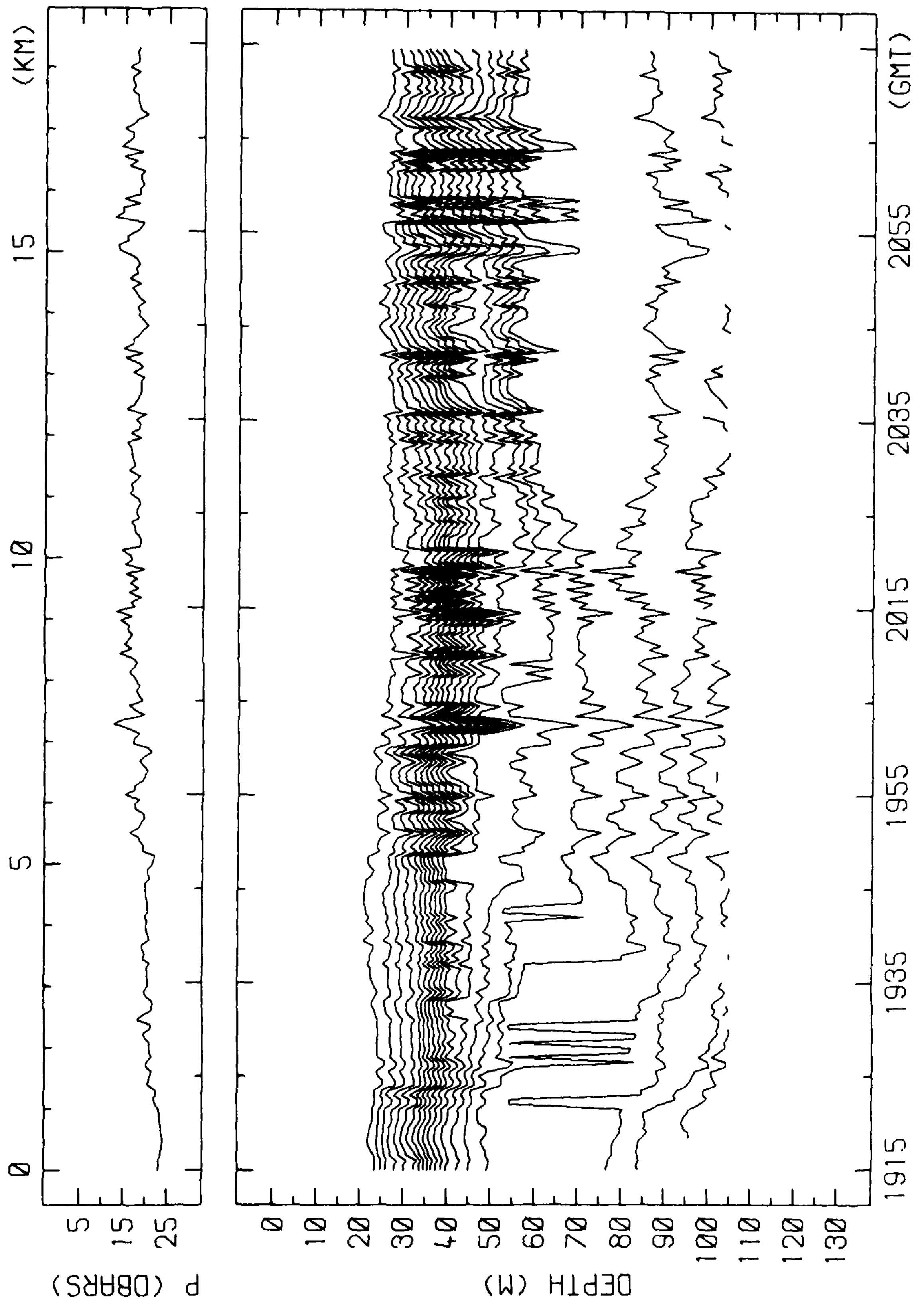


PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 14-SEP-81

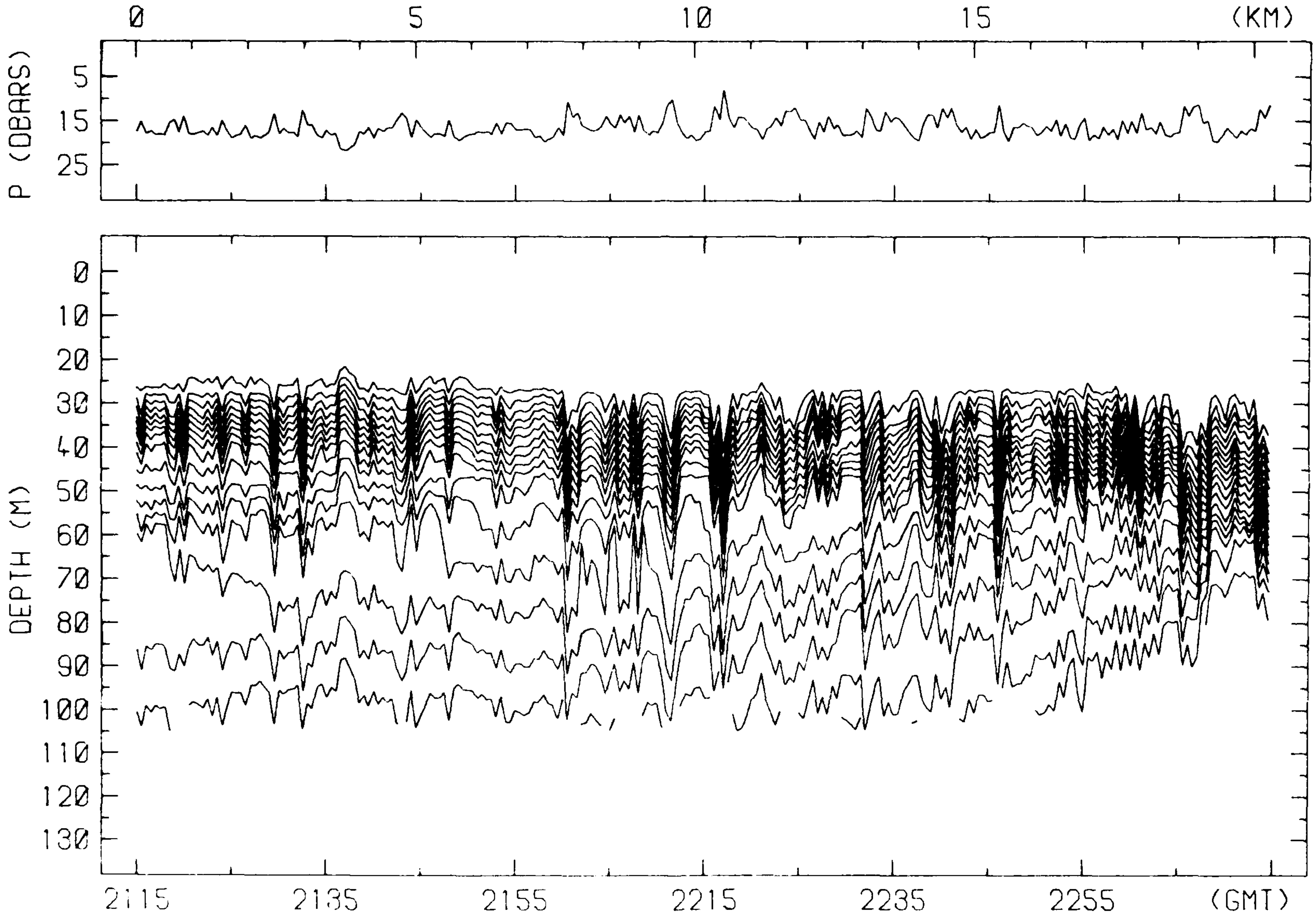

P (DBARS)
20
30
0
5
10
(KM)
DEPTH (M)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
0930
0950
1010
1030
1050
1110
(GMT)
PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 14-SEP-81



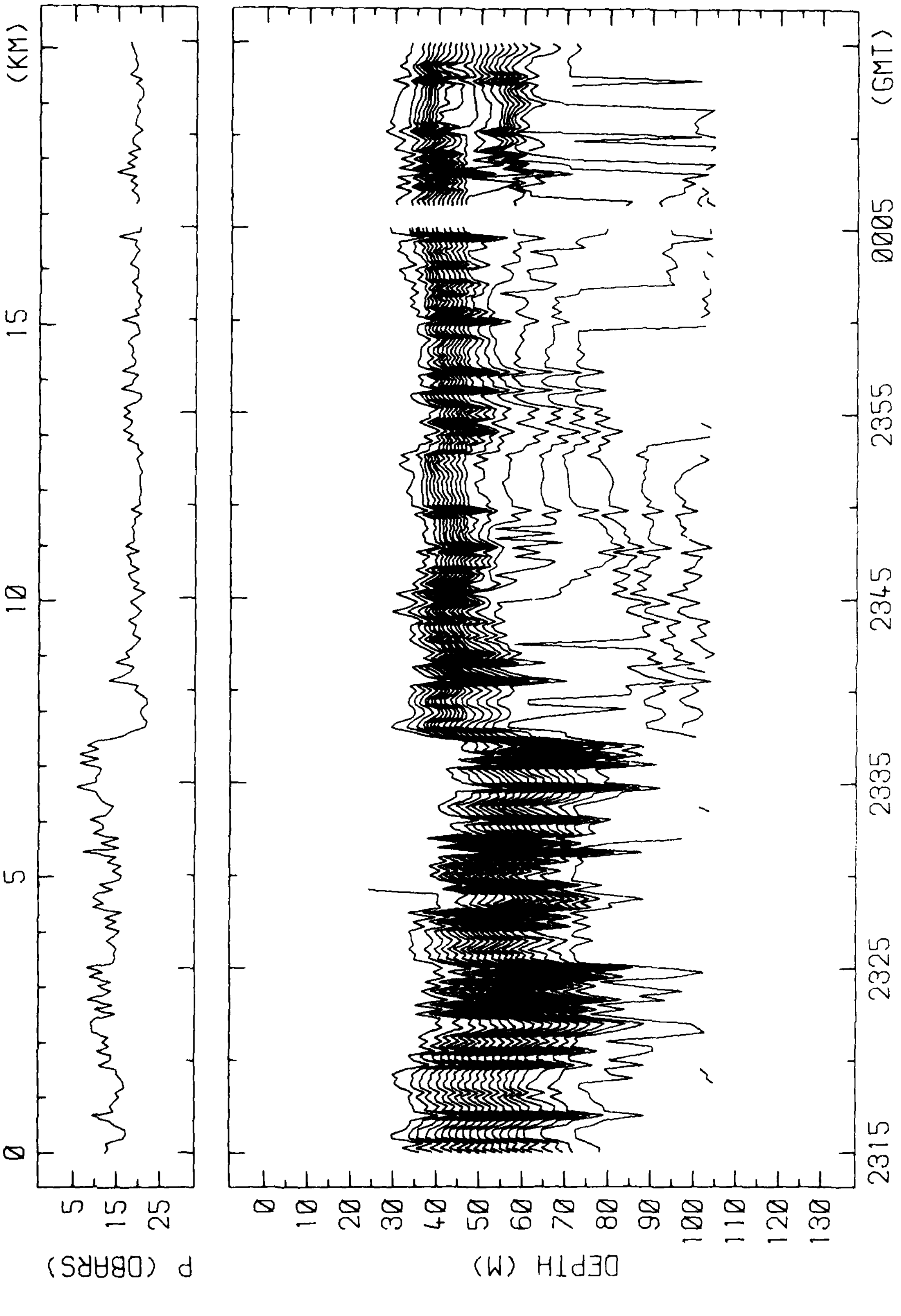
PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 14-SEP-81



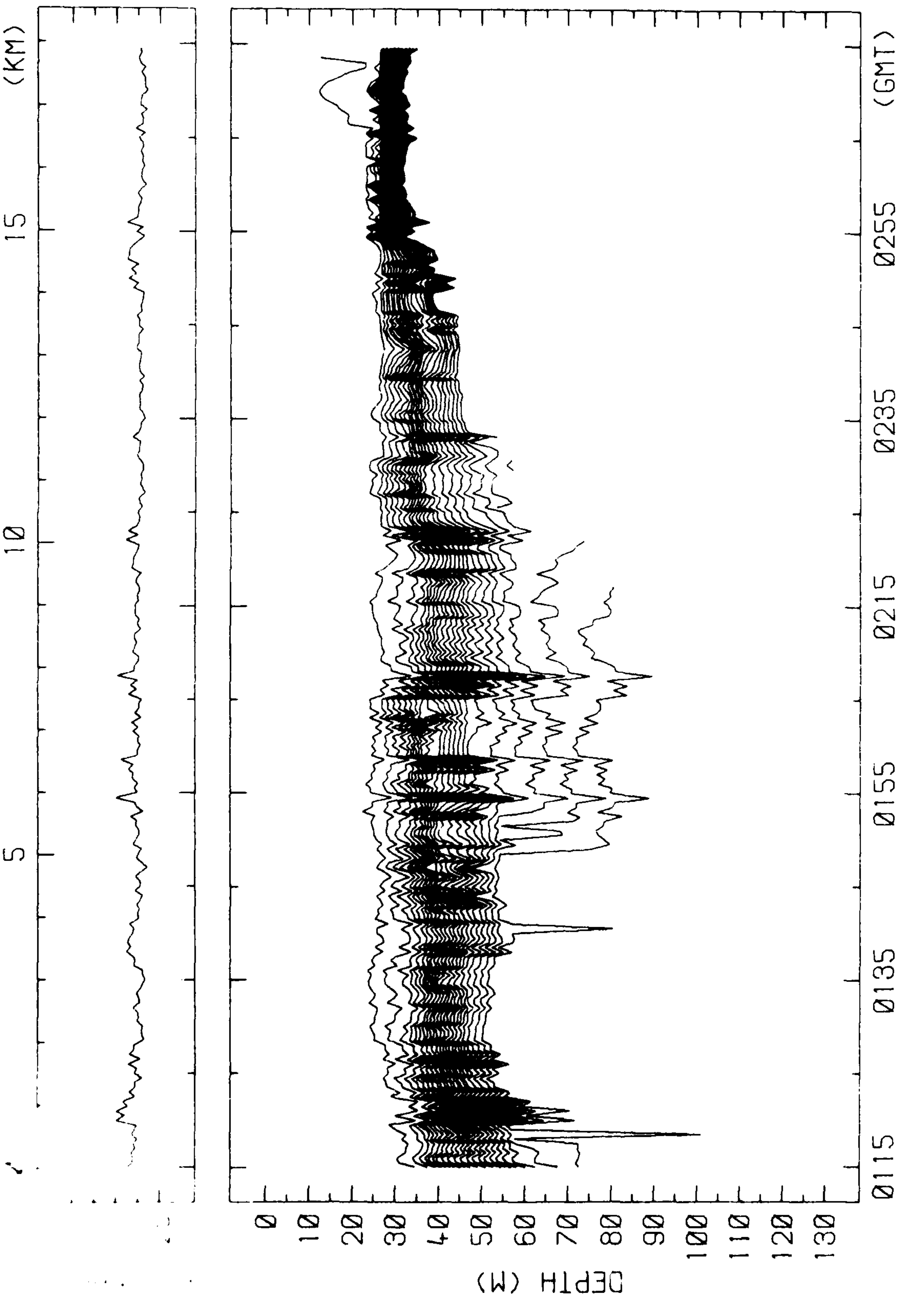
PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 17-SEP-81



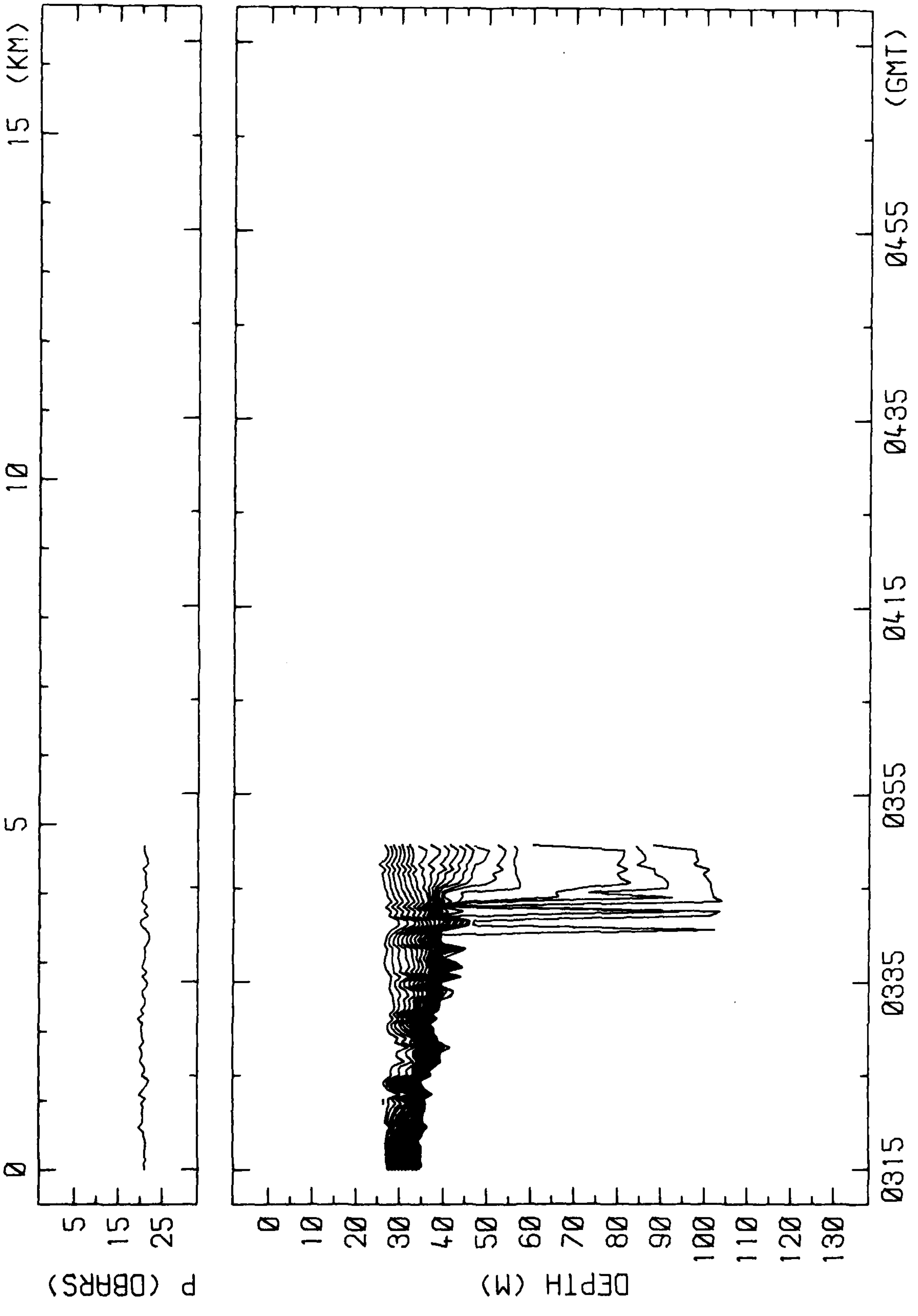
PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 17-SEP-81



PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 17,18-SEP-81



PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 18-SEP-81

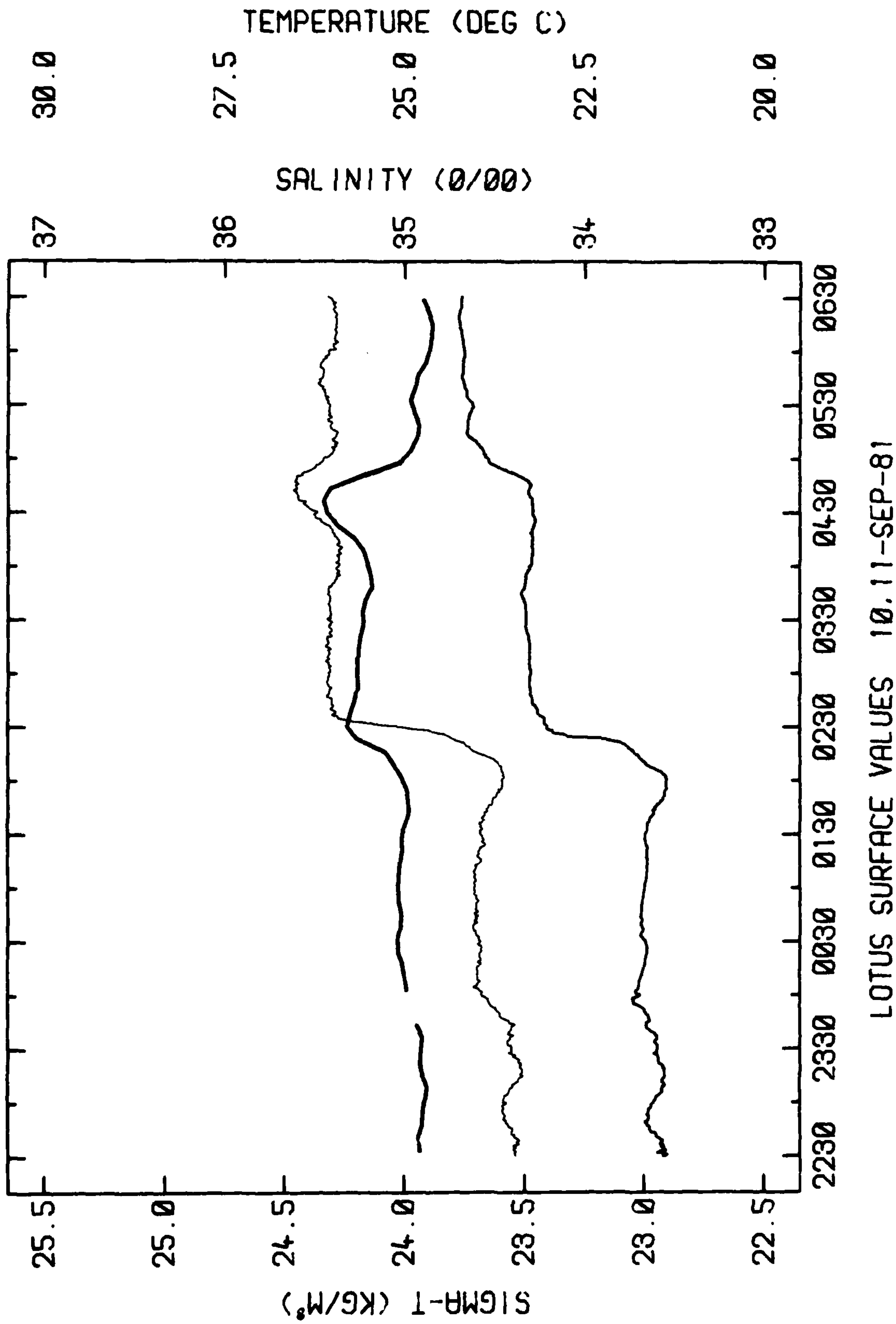


PRESSURE AND ISOTHERM DEPTH VS TIME/DISTANCE 18-SEP-81

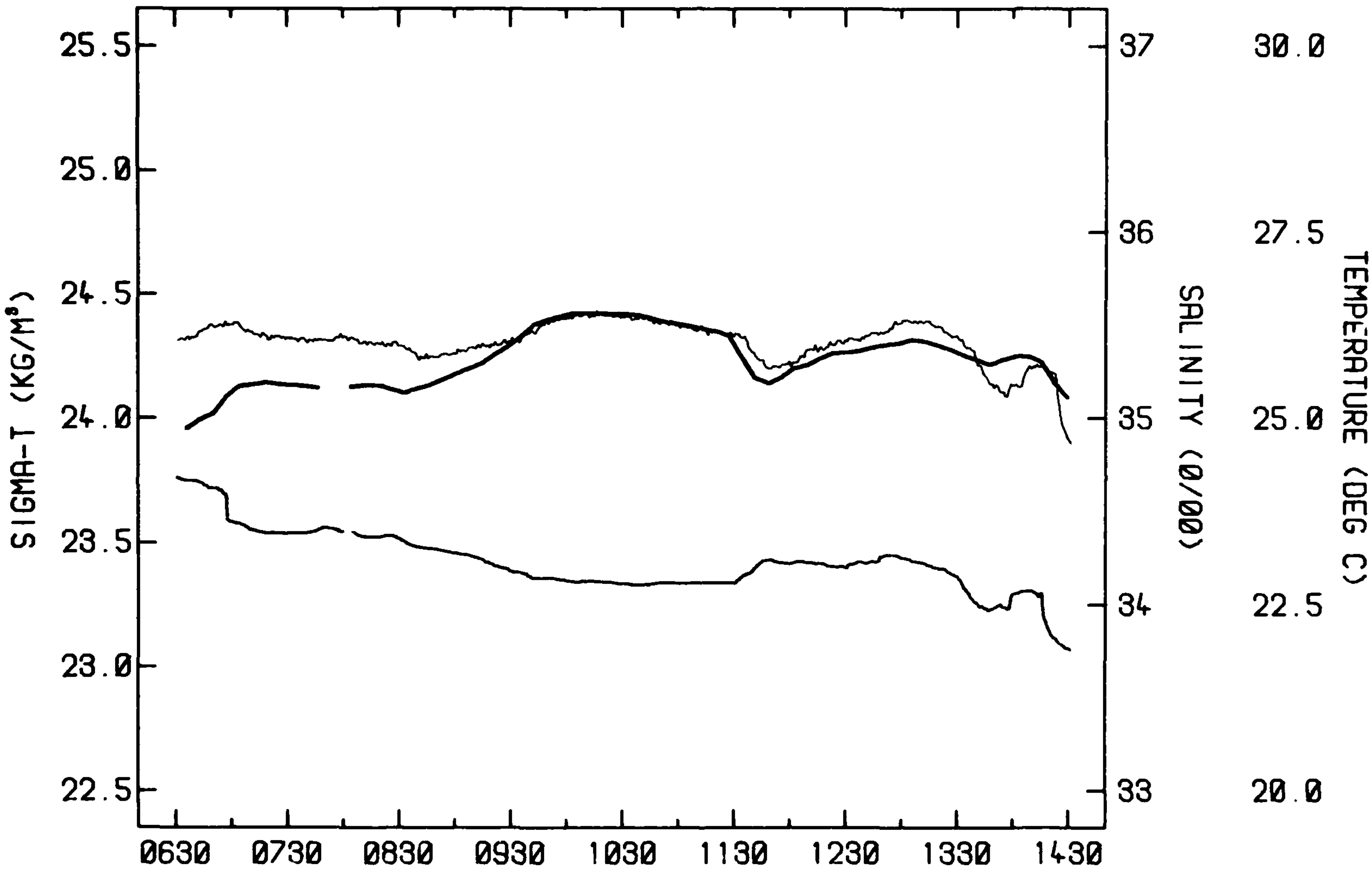
APPENDIX C

Surface Salinity, Temperature and Density

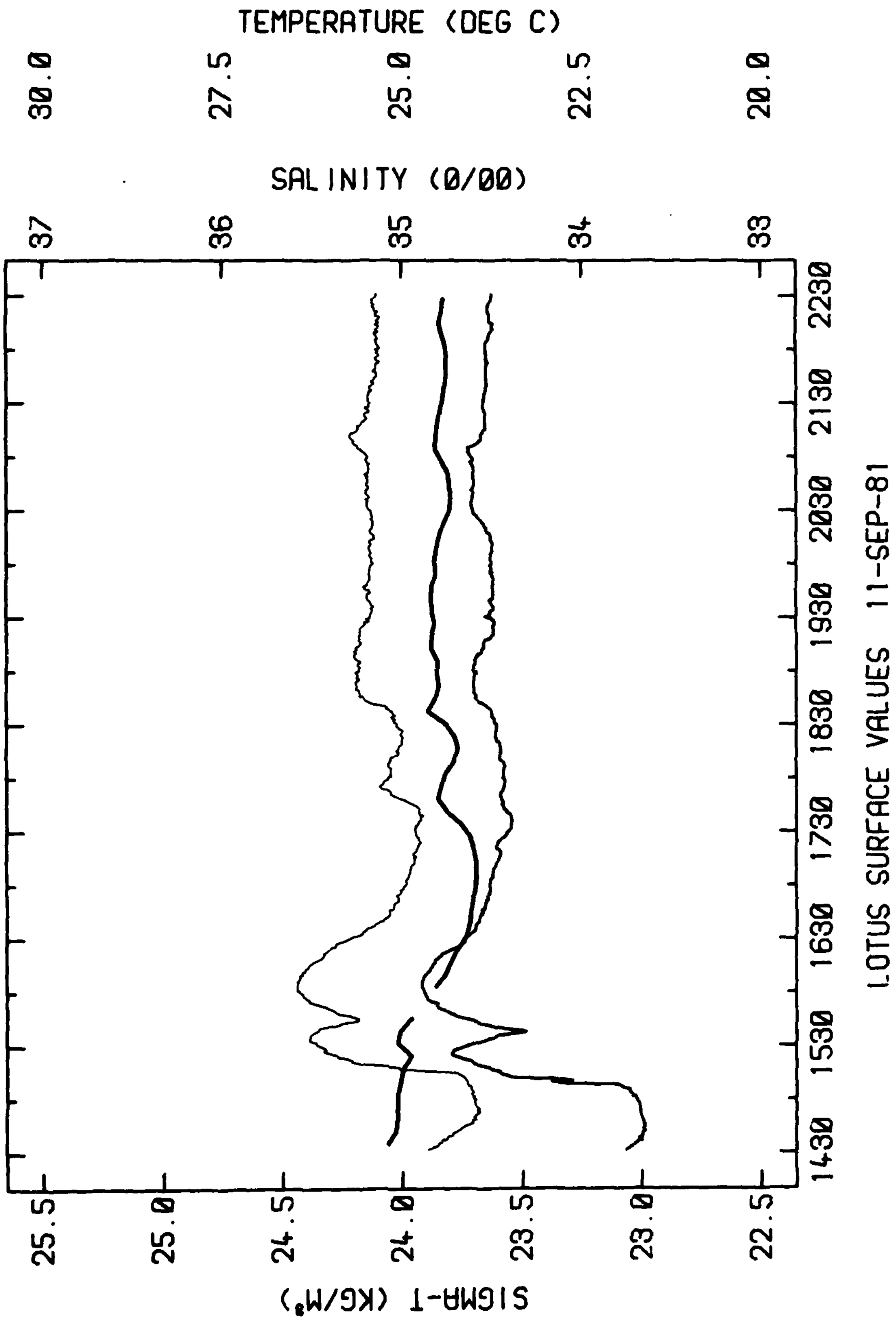
On the following eight pages are plots of surface salinity, temperature and density observed during Runs 1, 2 and 3. Surface salinity (light line) was measured in the ship's lab by use of a flow-through system (Baumann, 1981). Temperature (medium line) is from an upper thermistor on the chain at mean depths between 7.8 and 10.1 m (see Table 1). Density (heavy line) was computed from seven-minute averages of salinity and temperature with the salinity time series shifted back in time by seven minutes to compensate for the delay associated with circulation through the ship's sea water system. The plot of density is therefore smoother than salinity and temperature. Features in the salinity measurements are delayed by about seven minutes with respect to the same features in the temperature measurements.

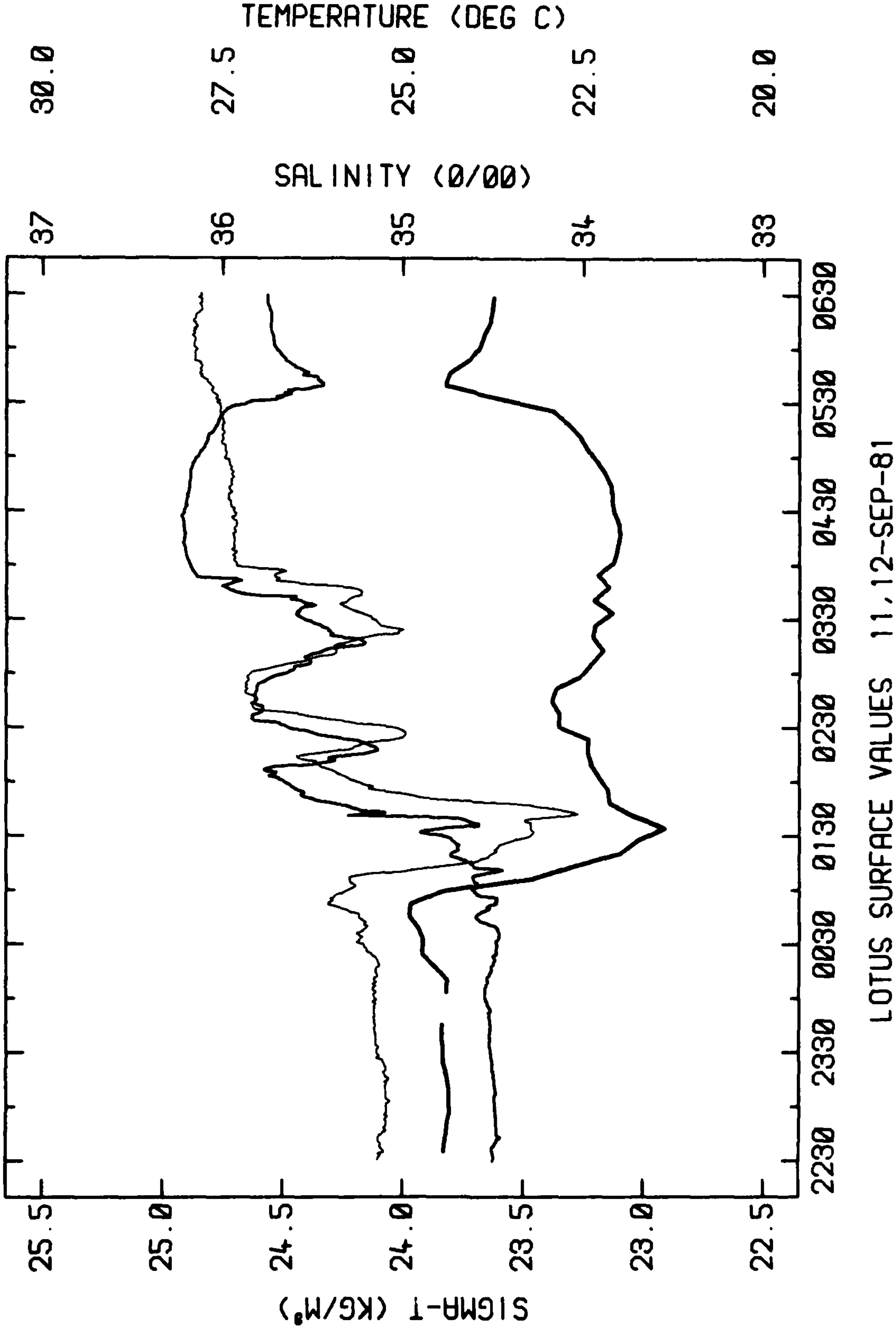


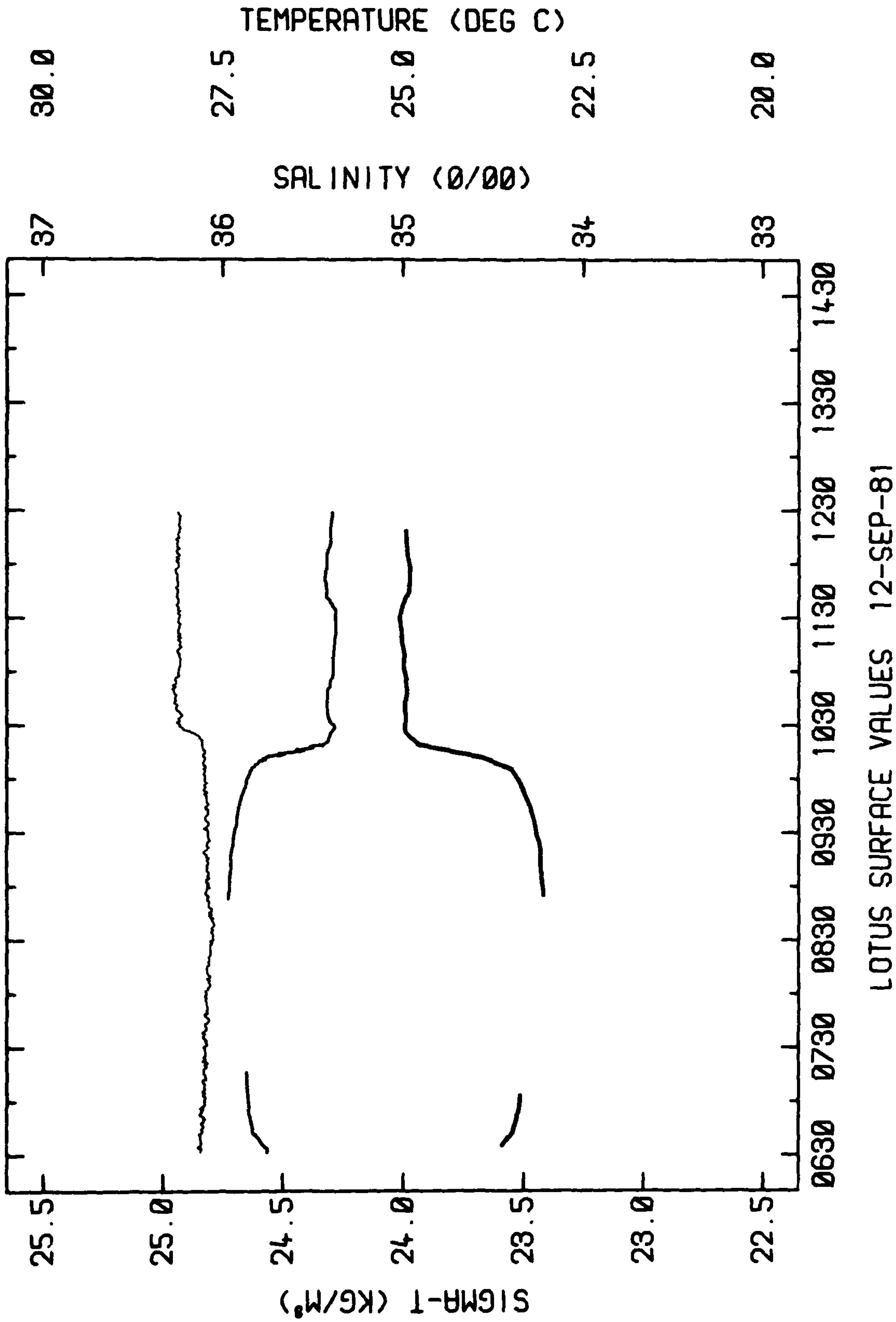
TEMPERATURE (DEG C)
30.0
27.5
25.0
22.5
20.0
SALINITY (0/00)
37
36
35
34
33
0630
0530
0430
0330
0230
0130
0030
2330
2230
25.5
25.0
24.5
24.0
23.5
23.0
22.5
SIGMA-T (KG/M³)
LOTUS SURFACE VALUES 10.11-SEP-81

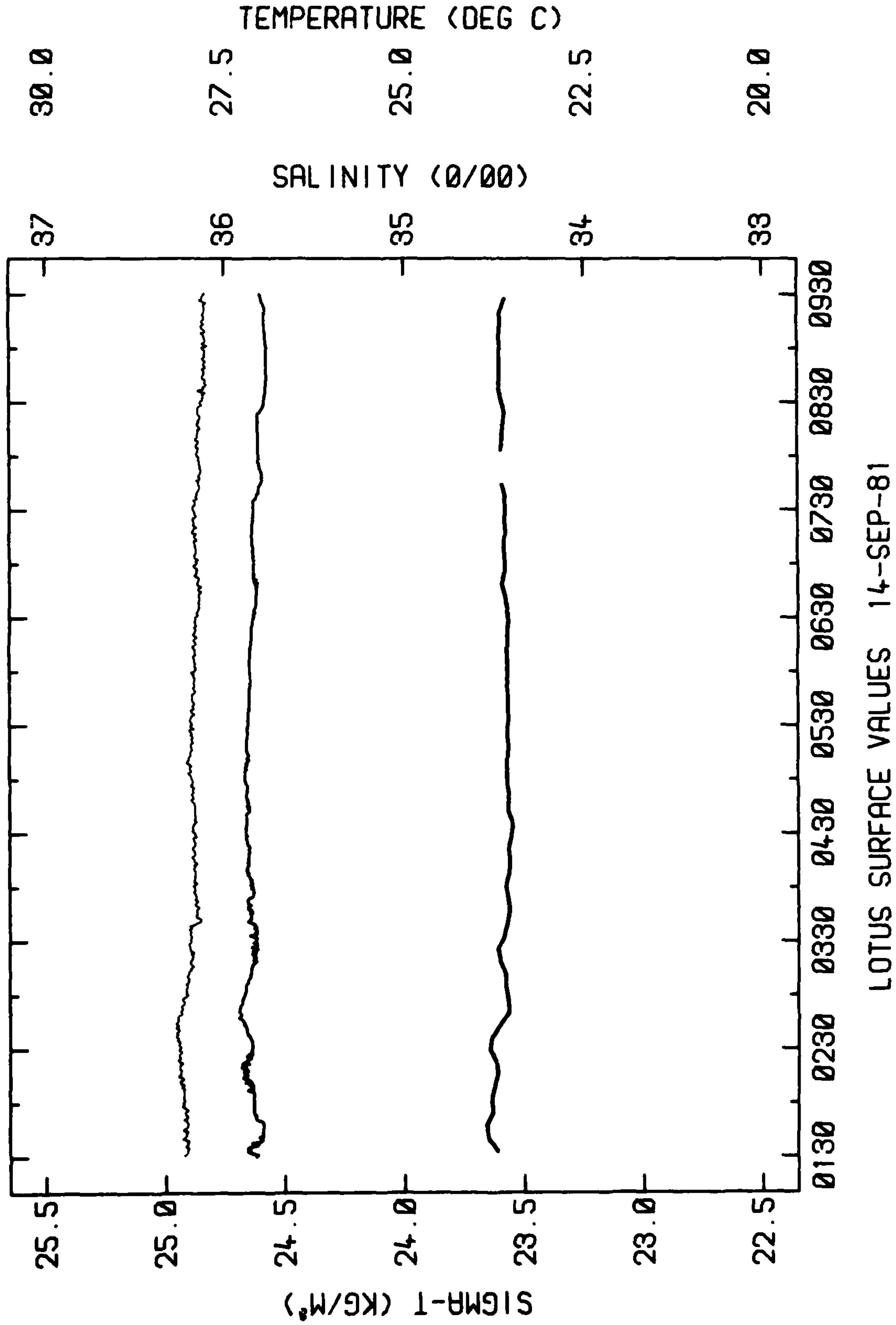


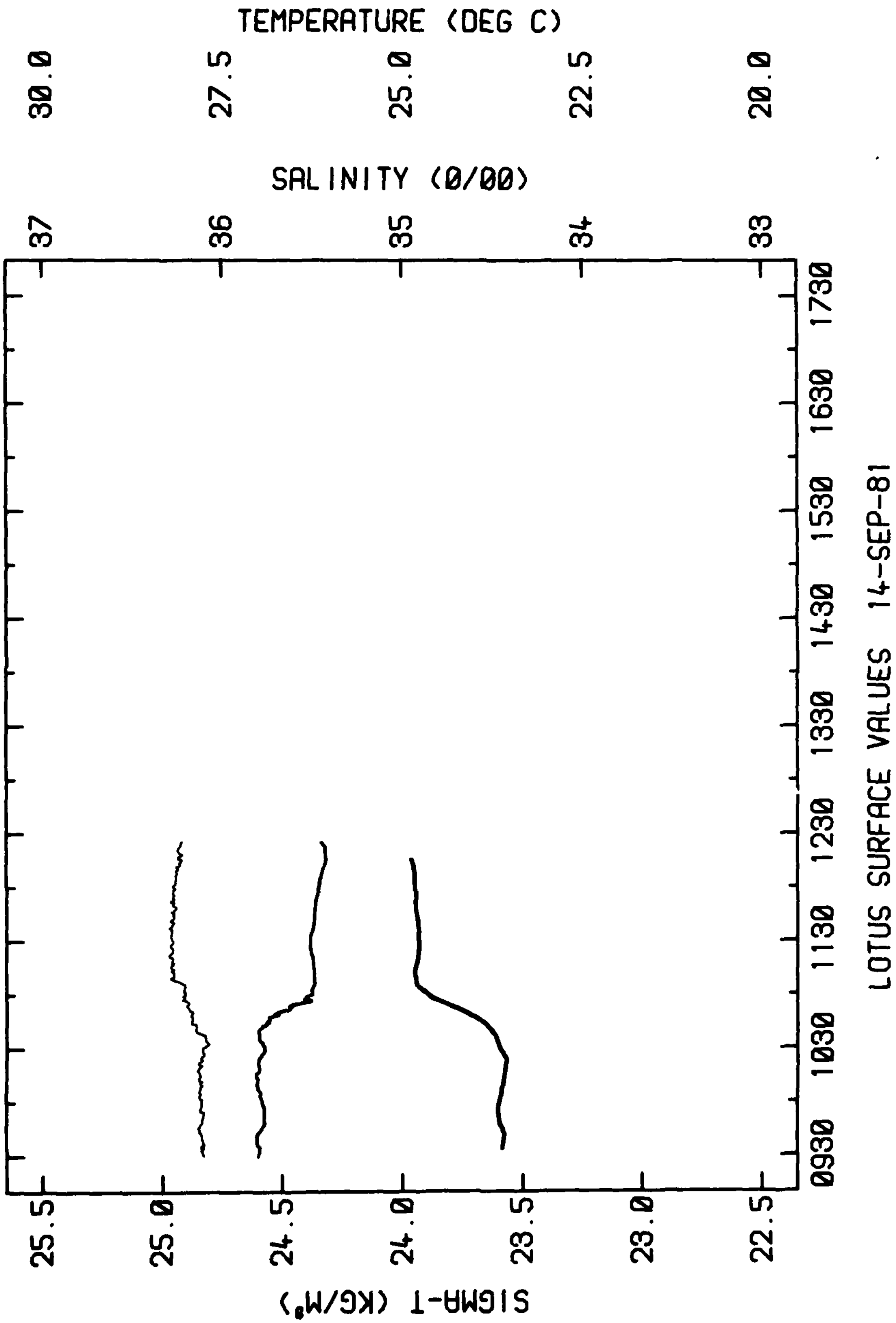
LOTUS SURFACE VALUES 11-SEP-81

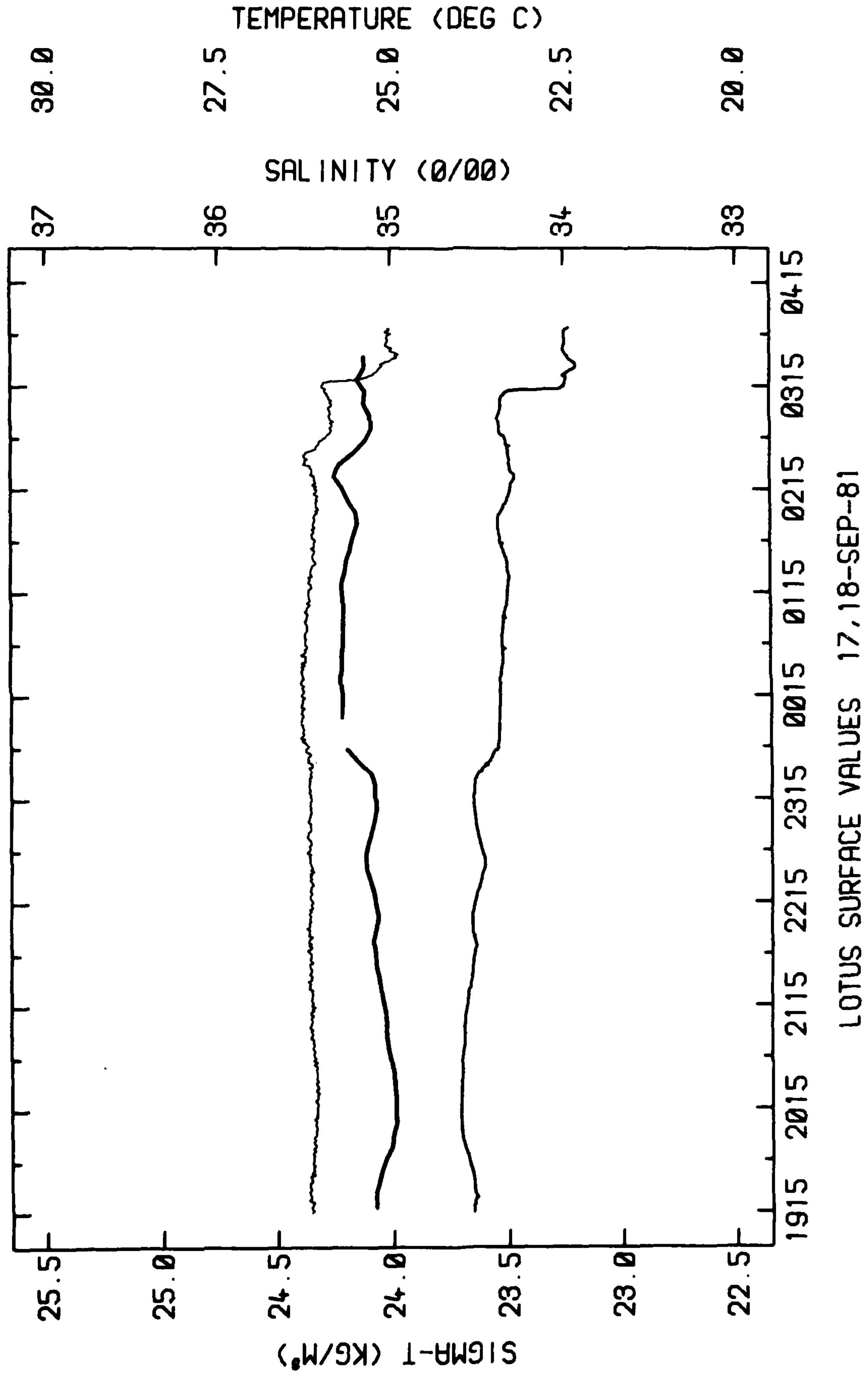

TEMPERATURE (DEG C)
30.0
27.5
25.0
22.5
20.0
SALINITY (0/00)
37
36
35
34
33
SIGMA-T (KG/M³)
25.5
25.0
24.5
24.0
23.5
23.0
22.5
1430
1530
1630
1730
1830
1930
2030
2130
2230
LOTUS SURFACE VALUES 11-SEP-81


TEMPERATURE (DEG C)
30.0
27.5
25.0
22.5
20.0
SALINITY (0/00)
37
36
35
34
33
SIGMA-T (KG/M3)
25.5
25.0
24.5
24.0
23.5
23.0
22.5
2230
2330
0030
0130
0230
0330
0430
0530
0630
LOTUS SURFACE VALUES 11,12-SEP-81


TEMPERATURE (DEG C)
30.0
27.5
25.0
22.5
20.0
SALINITY (0/00)
37
36
35
34
33
SIGMA-T (KG/M³)
25.5
25.0
24.5
24.0
23.5
23.0
22.5
0630
0730
0830
0930
1030
1130
1230
1330
1430
LOTUS SURFACE VALUES 12-SEP-81


TEMPERATURE (DEG C)
30.0
27.5
25.0
22.5
20.0
SALINITY (0/00)
37
36
35
34
33
0130
0230
0330
0430
0530
0630
0730
0830
0930
25.5
25.0
24.5
24.0
23.5
23.0
22.5
SIGMA-T (KG/M³)
LOTUS SURFACE VALUES 14-SEP-81


TEMPERATURE (DEG C)
30.0
27.5
25.0
22.5
20.0
SALINITY (0/00)
37
36
35
34
33
SIGMA-T (KG/M³)
25.5
25.0
24.5
24.0
23.5
23.0
22.5
0930
1030
1130
1230
1330
1430
1530
1630
1730
LOTUS SURFACE VALUES 14-SEP-81


TEMPERATURE (DEG C)
30.0
27.5
25.0
22.5
20.0
SALINITY (0/00)
37
36
35
34
33
0415
0315
0215
0115
0015
2315
2215
2115
2015
1915
LOTUS SURFACE VALUES 17,18-SEP-81
SIGMA-T (KG/M³)
25.5
25.0
24.5
24.0
23.5
23.0
22.5

APPENDIX D

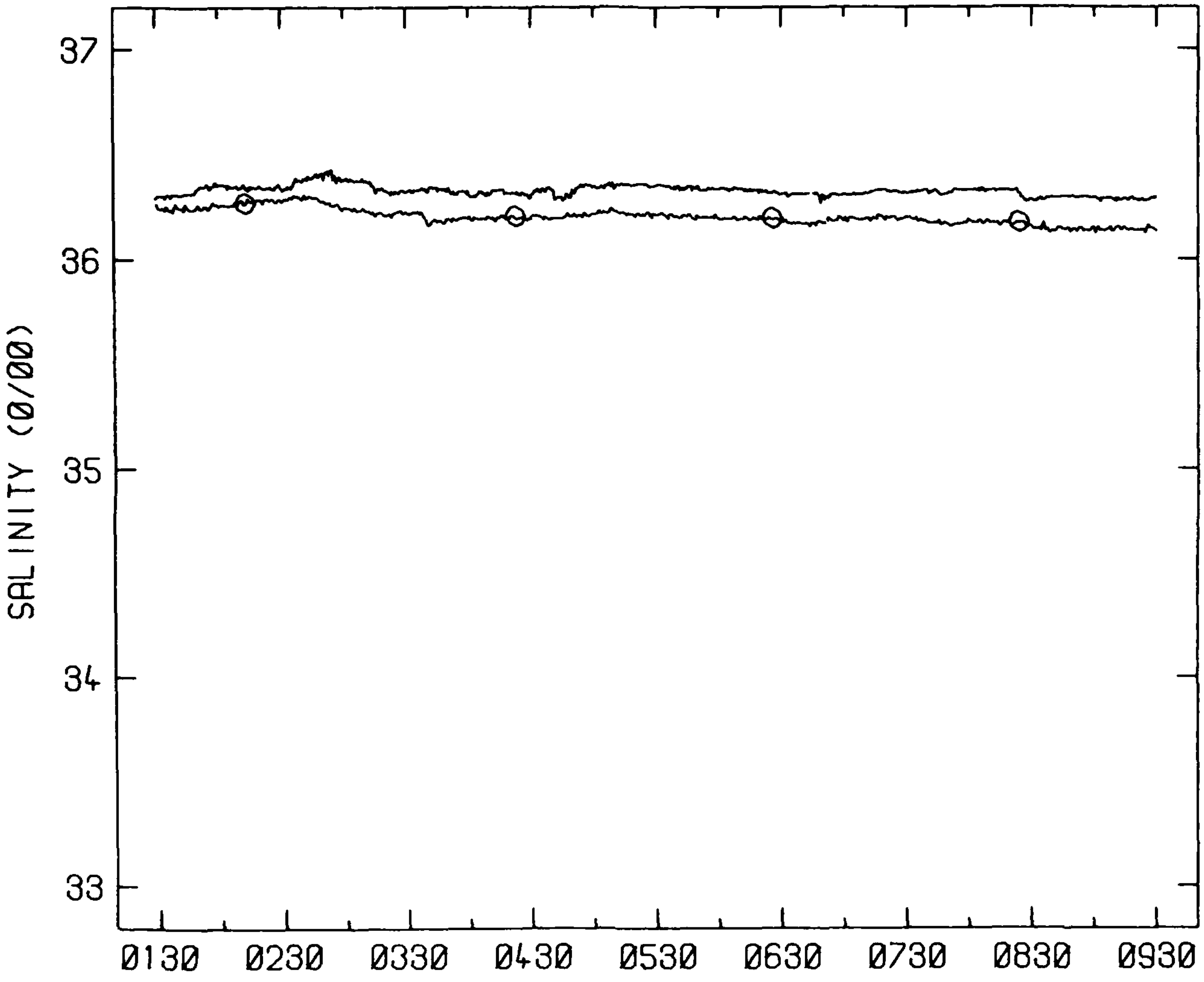
Salinity and Density From the Towed Chain

The first three figures, labeled "LOTUS surface salinity", show observations of surface salinity during Runs two and three measured by three independent methods. The circles are the salinity of bottle samples taken in the ship's lab. The lowermost trace is from a flow-through system in the ship's lab containing temperature and conductivity sensors manufactured by Sea-Bird. The calibration of the Sea-Bird conductivity sensor was supplied by the manufacturer. The systematic difference between the Sea-Bird and the bottle salinities is less than 0.01°/₀₀. The uppermost trace is salinity from conductivity and temperature sensors installed on the chain one-half meter apart at a mean depth of about 12 m. The magnitude of the fluctuations is similar despite the systematic difference. The sensors on the chain respond more rapidly to changes in surface properties than the shipboard instruments which are slowed by circulation of sea water through the ship's plumbing.

The next three figures, labeled "LOTUS surface values from chain", show salinity (light line), temperature (medium line) and density (heavy line) from conductivity and temperature sensors on the towed chain at a depth of about 12 m (see Table 1). The absolute values of salinity and

density are in error because no correction has been made for the systematic error in salinity shown on the previous three pages.

The last three figures of this appendix, labeled "LOTUS deep values from chain" show salinity (light line), temperature (medium line) and density (heavy line) from conductivity and temperature sensors at a depth of about 110 and 100 m during Runs two and three respectively. The absolute calibration of the conductivity sensor was significantly in error which caused salinity and density to be unrealistically large. The fluctuations are considered realistic.



LOTUS SURFACE SALINITY 14-SEP-81

AD-A116 135 OREGON STATE UNIV CORVALLIS SCHOOL OF OCEANOGRAPHY F/G 8/10
TOWED THERMISTOR CHAIN OBSERVATIONS ACROSS THE GULF STREAM.(U)
FEB 82 R J BAUMANN, L M DEWITT, M D LEVINE N00014-79-C-0004

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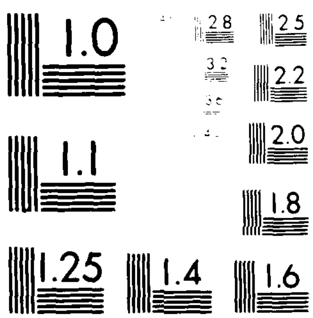
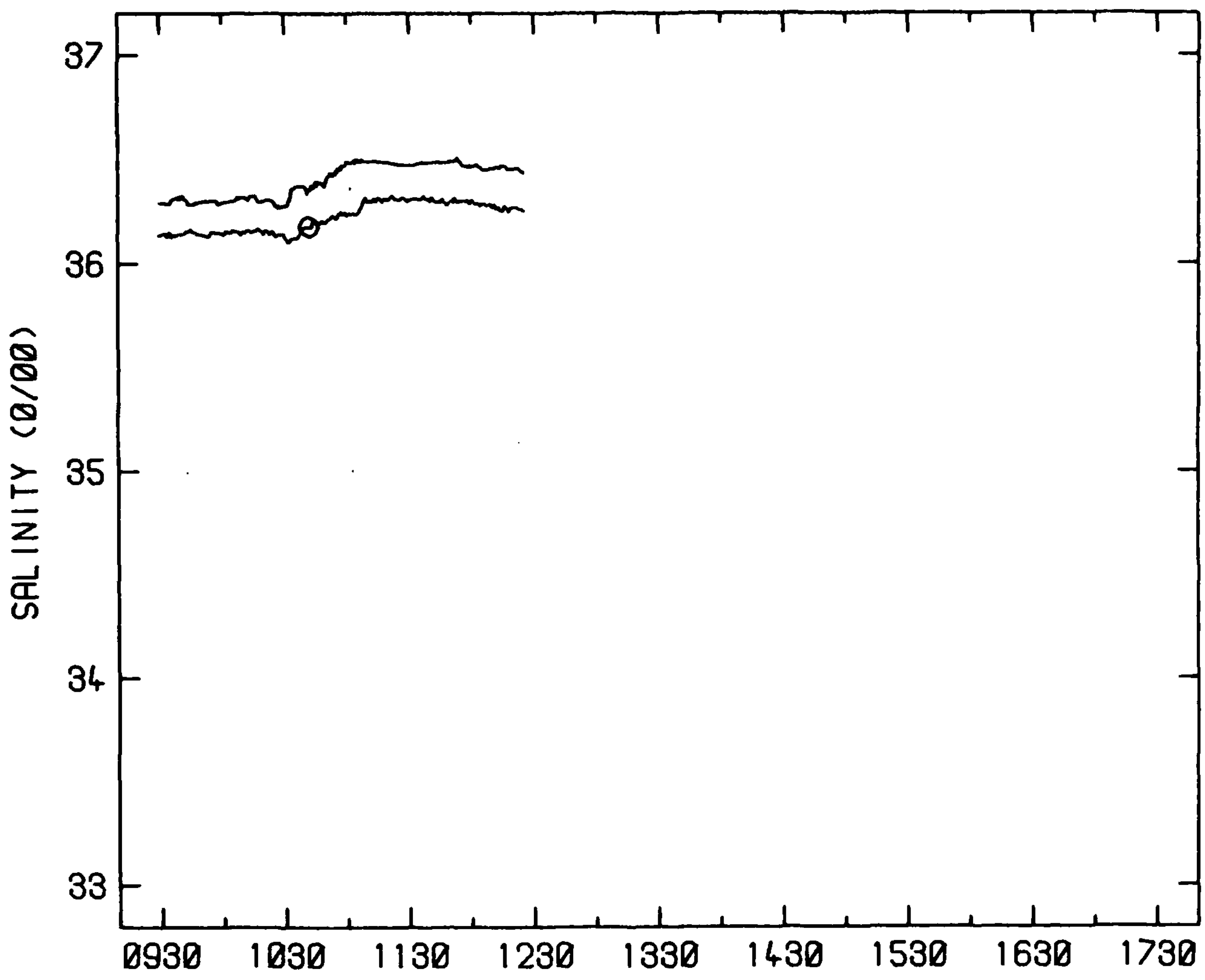
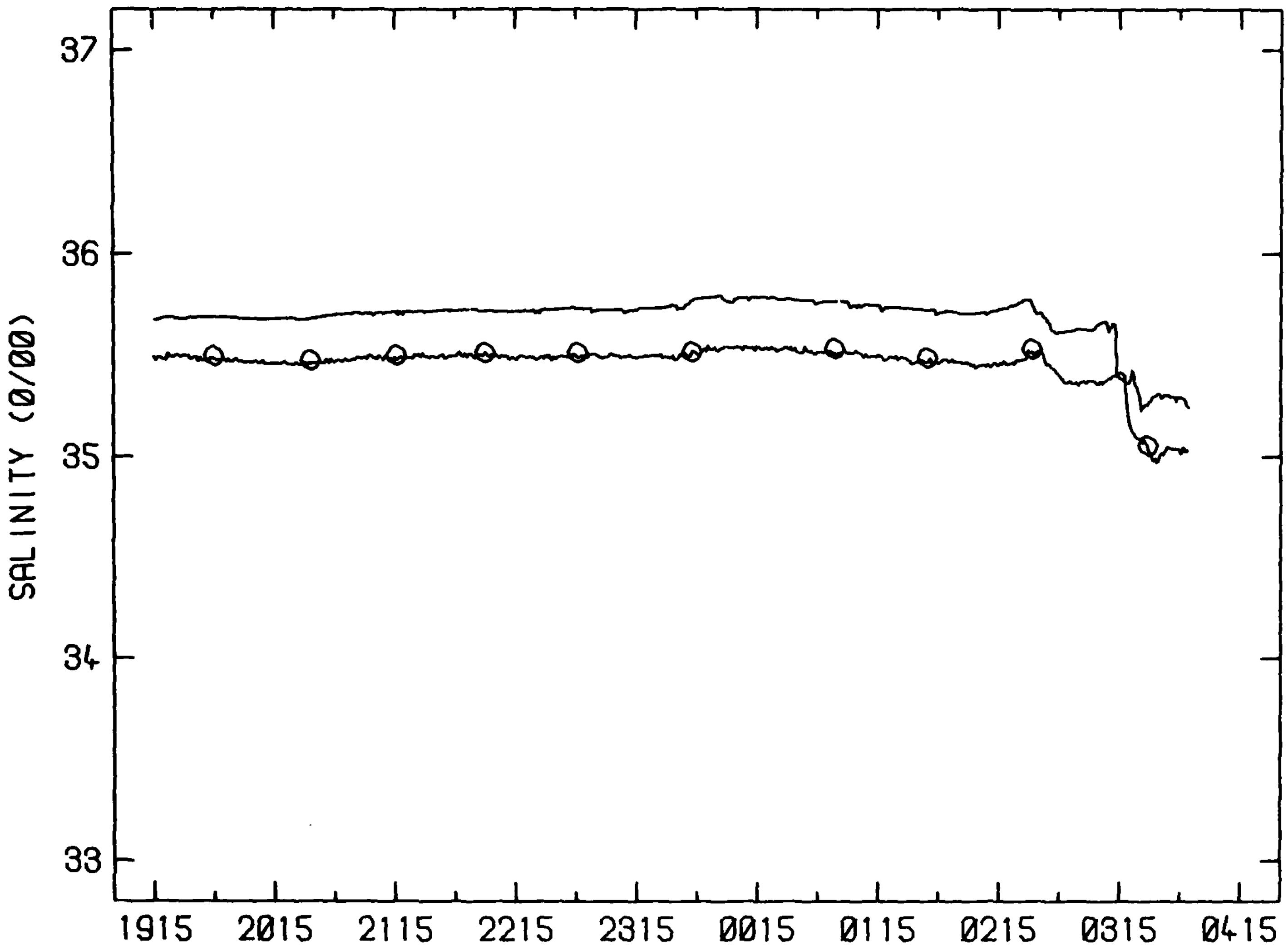


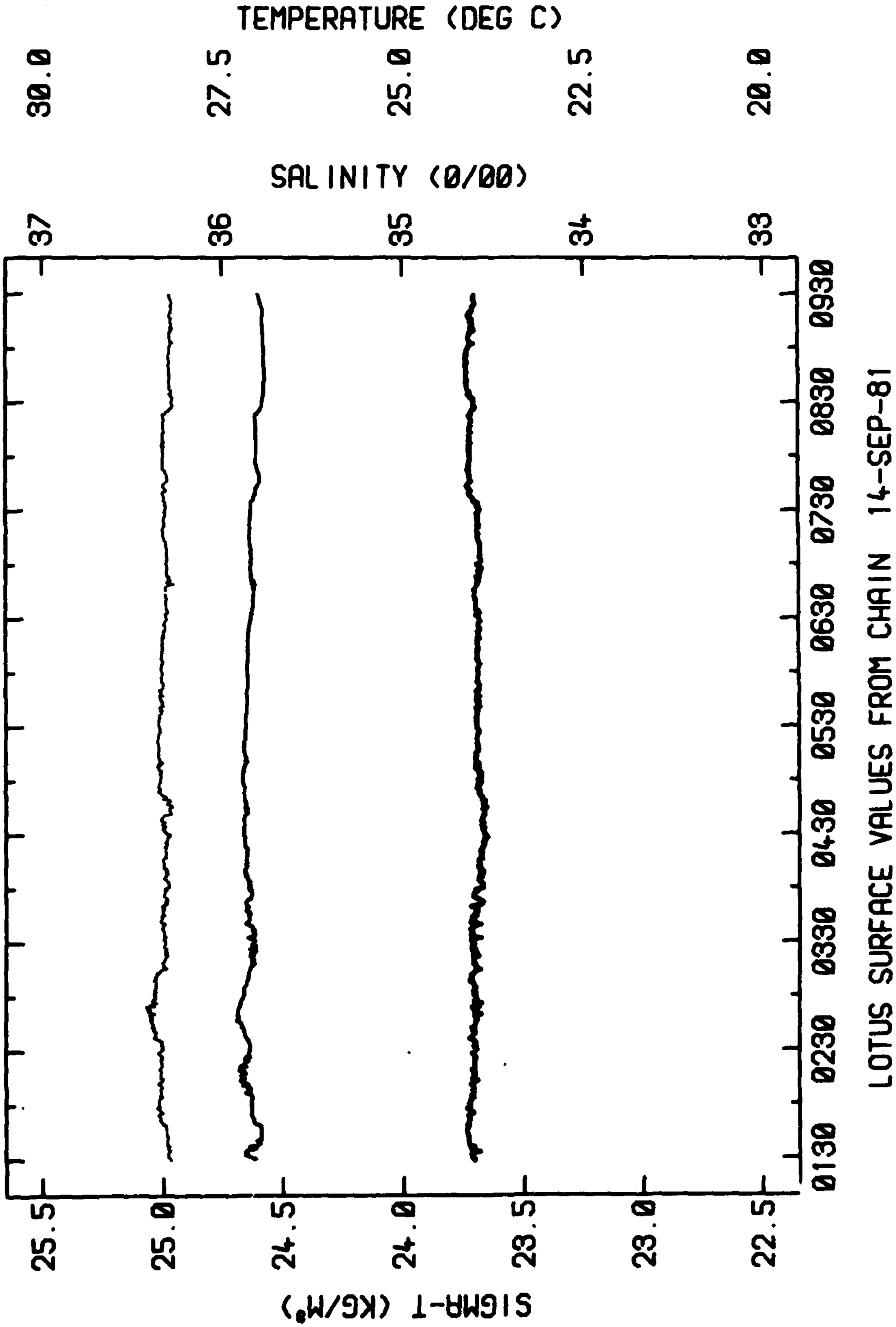
MICROCOPY RESOLUTION TEST CHART

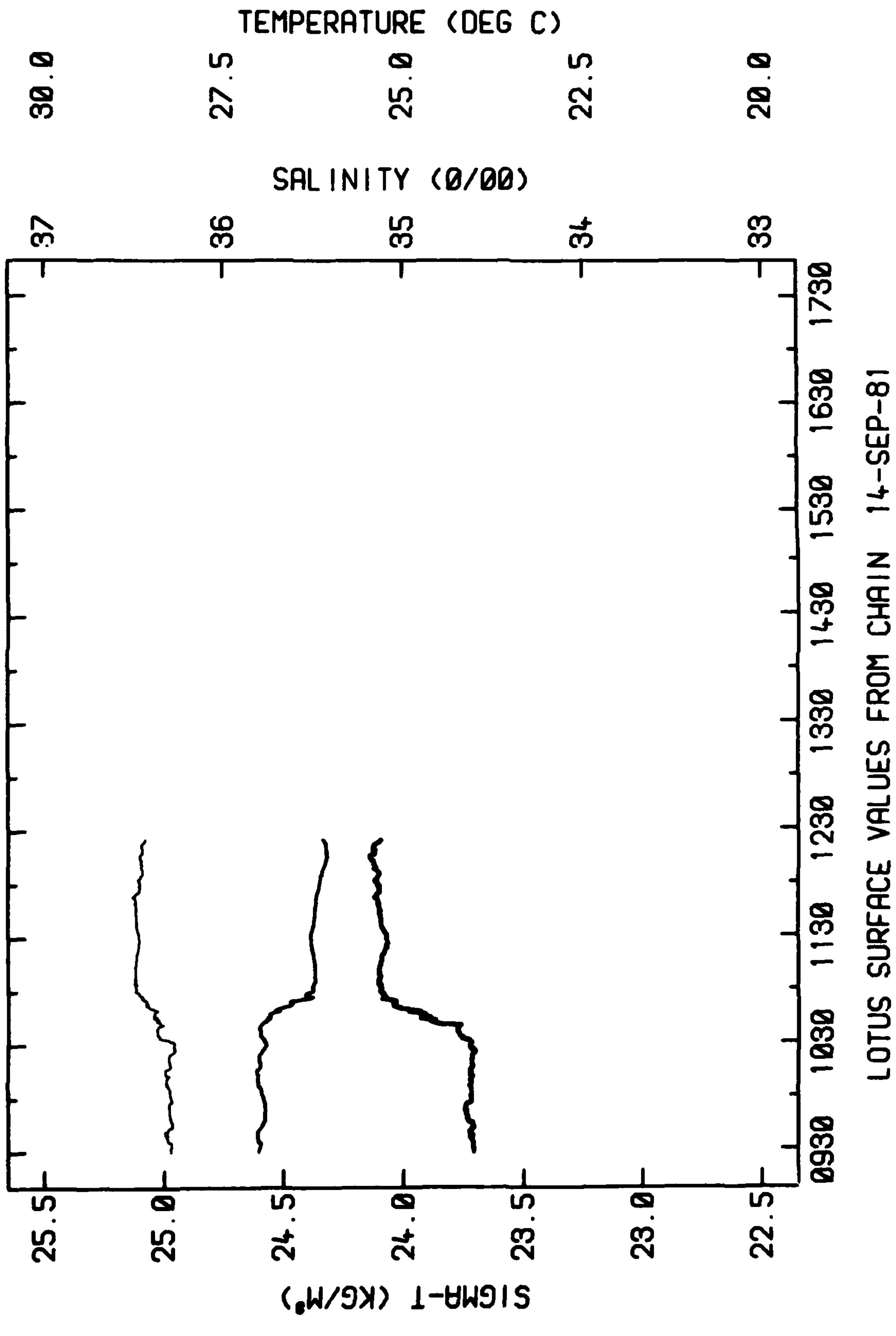


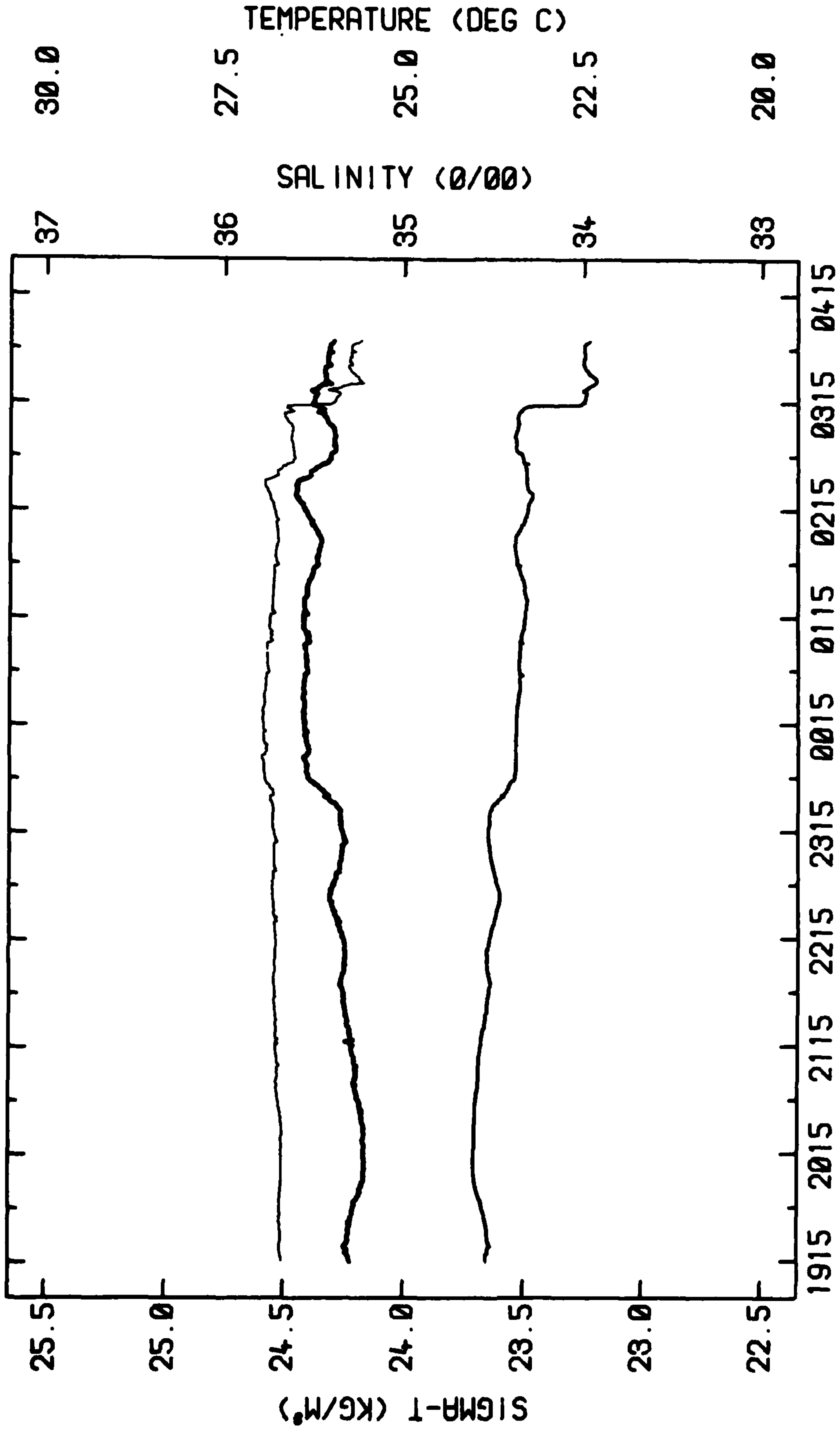
LOTUS SURFACE SALINITY 14-SEP-81



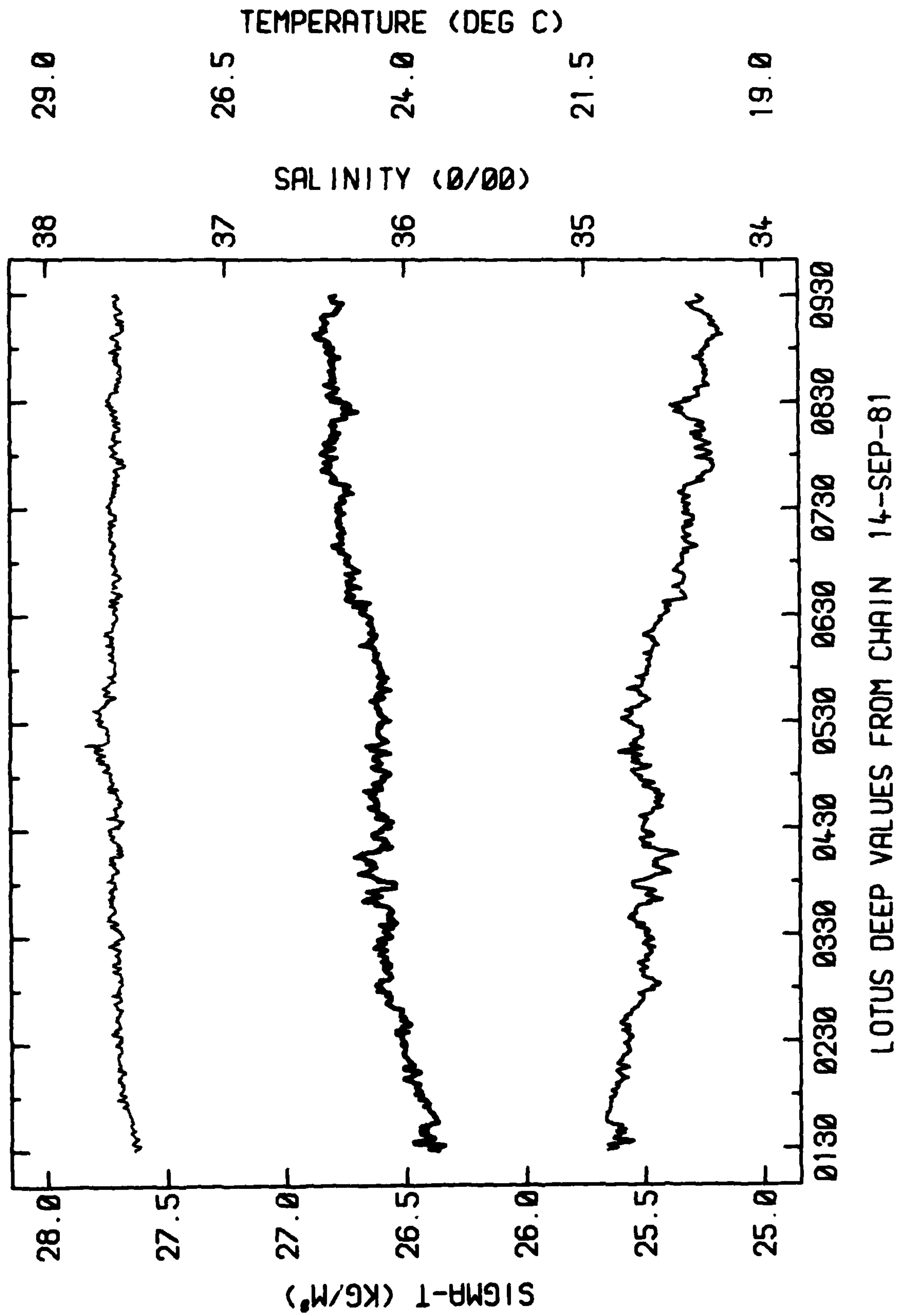
LOTUS SURFACE SALINITY 17,18-SEP-81

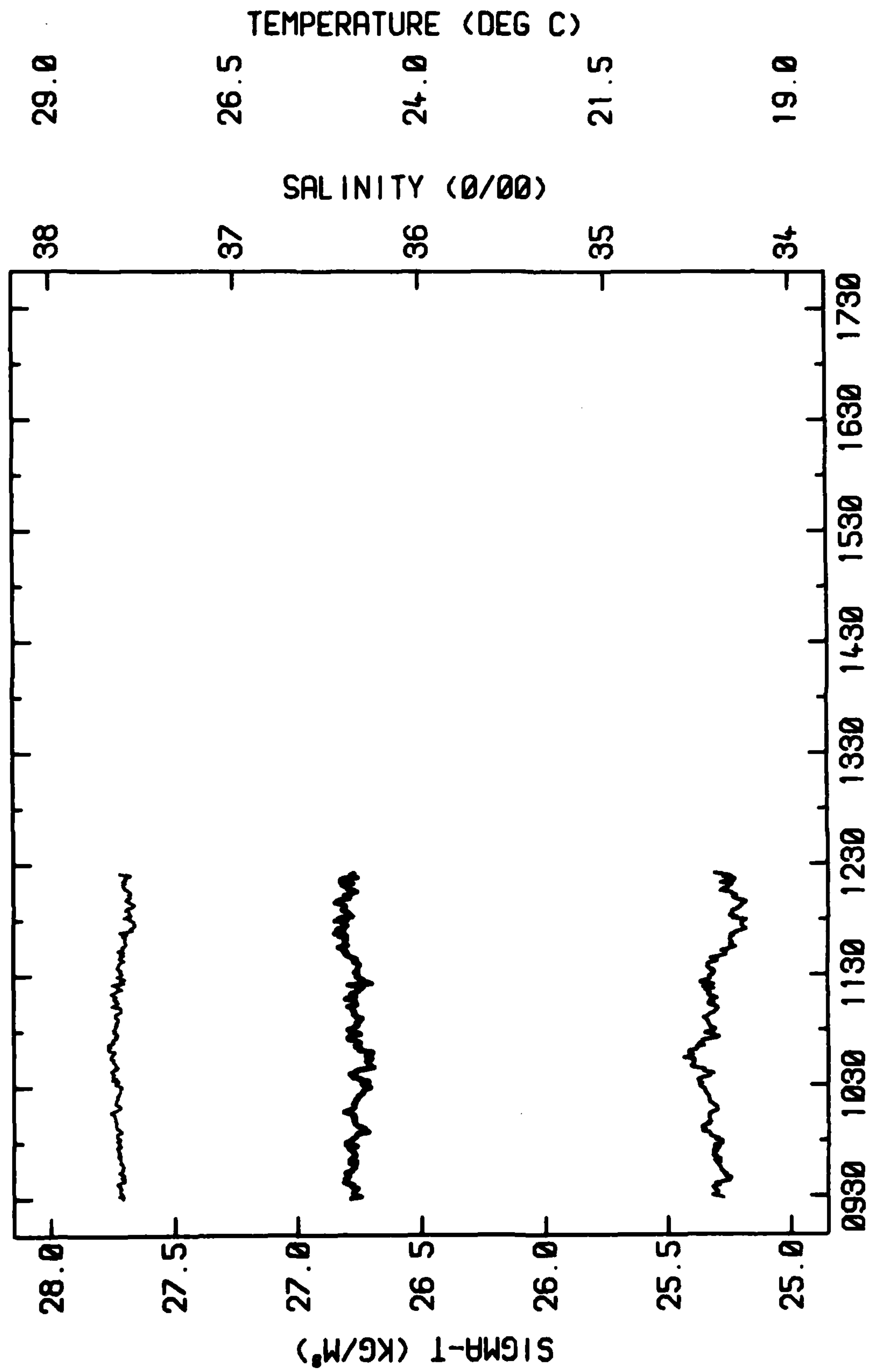

TEMPERATURE (DEG C)
30.0
27.5
25.0
22.5
20.0
SALINITY (0/00)
37
36
35
34
33
0930
0830
0730
0630
0530
0430
0330
0230
0130
25.5
25.0
24.5
24.0
23.5
23.0
22.5
SIGMA-T (KG/M³)
LOTUS SURFACE VALUES FROM CHAIN 14-SEP-81


TEMPERATURE (DEG C)
30.0
27.5
25.0
22.5
20.0
SALINITY (0/00)
37
36
35
34
33
25.5
25.0
24.5
24.0
23.5
23.0
22.5
SIGMA-T (KG/M³)
0930
1030
1130
1230
1330
1430
1530
1630
1730
LOTUS SURFACE VALUES FROM CHAIN 14-SEP-81

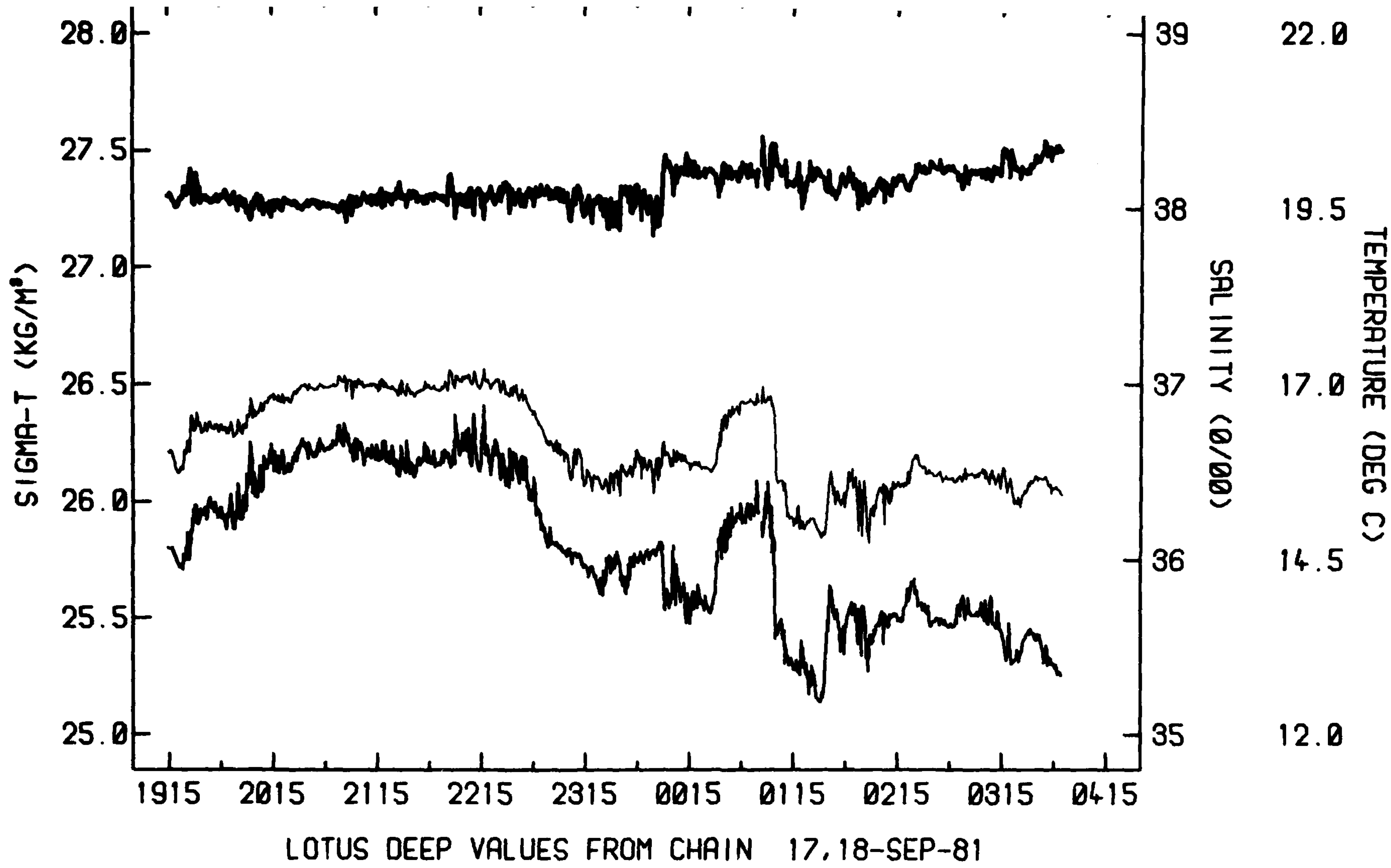


LOTUS SURFACE VALUES FROM CHAIN 17,18-SEP-81


TEMPERATURE (DEG C)
29.0
26.5
24.0
21.5
19.0
SALINITY (0/00)
38
37
36
35
34
0930
0830
0730
0630
0530
0430
0330
0230
0130
LOTUS DEEP VALUES FROM CHAIN 14-SEP-81
28.0
27.5
27.0
26.5
26.0
25.5
25.0
SIGMA-T (KG/M³)



LOTUS DEEP VALUES FROM CHAIN 14-SEP-81


28.0
27.5
27.0
26.5
26.0
25.5
25.0
SIGMA-T (KG/M³)
39
38
37
36
35
SALINITY (0/00)
22.0
19.5
17.0
14.5
12.0
TEMPERATURE (DEG C)
1915 2015 2115 2215 2315 0015 0115 0215 0315 0415
LOTUS DEEP VALUES FROM CHAIN 17,18-SEP-81

7-8

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